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LESIONS OF THE SPINAL EPIDURAL SPACE PRODUCING CORD COMPRESSION

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The pathologic changes of tumors occurring in the epidural space of the spinal intravertebral canal have received less attention than have the pathologic changes of intradural tumors. We have, therefore, reviewed the spinal extradural compressive lesions encountered in a ten year period (1934-1944) in the material of the Laboratory of Neurosurgical Pathology of the Hospital of the University of Pennsylvania. These formed a series of 54 cases and comprised roughly 30 per cent of the total number of mass lesions of the spinal canal.

The material is entirely surgical, all patients having undergone laminectomy for relief of cord compression. Symptoms of cord involvement were in all cases the primary complaint, even though the lesion was subsequently found to extend beyond the intervertebral canal, to originate at a distance or even to be a part of systemic disease.

The pathologic material has been carefully reviewed and correlated with the clinical course. The types of tumors encountered proved to be of unusual interest, a majority being malignant. Many general terms, particularly the nonspecific one of "sarcoma," were eliminated and a more precise classification achieved. This was all the more satisfactory when fairly distinct clinical pictures could be associated with the major groups.

Table 1 enumerates the various types of lesions and the number of each in our series.

TABLE 1.—*Types of Lesions and Number of Each in This Series*

Metastatic carcinoma		9
Myeloma		7
Neuroblastoma		6
Giant cell tumor of bone		3
Miscellaneous epidural tumors		10
Lymphosarcoma	2	
Tumors of adipose tissue	2	
Blood vessel tumors	2	
Leukemic infiltration	1	
Neurilemmoma	1	
Unclassified	2	
Spinal extradural cyst		2
Epidural hemorrhage		3
Epidural infectious processes		14
Acute suppuration	6	
Tuberculous granuloma	2	
Syphilitic granuloma	3	
Nonspecific granuloma	3	
Total		54

METASTIC CARCINOMA

The patients proved to have metastatic carcinoma causing cord compression were over 50 years of age, except for a 27 year old man with a probable primary kidney tumor (table 2). Symptoms on admission to the hospital were in almost every case confined to the nervous system and fell into the two categories of root compression and cord compression. Symptoms of root compression antedated the latter, usually by several months. The progression of the paraplegia was extremely rapid, and surgical treatment was resorted to for its relief in a relatively short time after its onset (generally a matter of weeks). In more than half the cases, bony erosion of the vertebral canal at the level of the lesion could be demonstrated by roentgen ray examination. The systemic nature of the lesion was often suggested by a history of pronounced loss of weight, its onset preceding the focal symptoms of the metastatic lesion. An interesting feature of this group was the uniform obscurity of the site of origin of the primary tumor. In 6 of the 9 cases the primary site was never determined. Autopsies were not performed on most of these patients, since they died at home, some distance from the hospital (2 patients could not be contacted after their discharge from the hospital). Autopsy in 1 of the few instances in which the primary site was ultimately discovered revealed a previously unsuspected primary carcinoma of the lung. In another patient, postoperative roentgenography of the chest showed evidence of a primary neoplasm of the lung. Finally, the youngest patient

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in this group had a palpable mass thought to involve the kidney, but the nature of the lesion was never verified (case 4).

when the diagnosis is clear because of uniform inability to relieve the cord symptoms by decompressive laminectomy. It has been suggested

TABLE 2.—*Metastatic Carcinoma (16.7 per Cent)*

Case; Sex; Age, Yr.	Duration of Pain	Duration of Cord Compression	Roentgenologic Findings	Systemic Symptoms	Site of Lesion	Primary Source	Operative Result	Final Result	Pathologic Comment
1 P 64	5 mo.	2 wk.	Spine normal; chest normal	20 lb. loss of weight	T-9, T-10	?	Pain relieved	Died 3 yr. postoperatively; metastases to bones and abdominal cavity; no autopsy	Undifferentiated carcinoma
2 M 48	3 wk.	3 days	Erosion pedicle of T-3; chest normal	None	T-4, T-7	?	Unimproved	Died 1 wk. postoperatively; no autopsy	Adenocarcinoma
3 M 61	7 mo.	None	Spine normal; chest normal	Anemia; loss of 42 lb.	C-7	?	Relief of pain	No follow-up	Adenocarcinoma
4 M 27	9 mo.	8 days	Laminas and body of L-3 vertebra eroded; chest normal	Retroperitoneal mass in region of right kidney; loss of 42 lb.	L-3	Right kidney ?	Relief of pain; bladder function regained	Died 25 days postoperatively; no autopsy	Undifferentiated carcinoma; largely necrotic
5 M 43	5 mo.	2 mo.	Spine normal; chest normal	40 lb. loss of weight	L-3, L-5	? Completely studied	Relief of pain	No follow-up	Adenocarcinoma
6 M 66	18 mo.	1 mo.	Spine normal; chest normal	Loss of weight	T-4	Lung	Unimproved	Died 2 mo. postoperatively; autopsy revealed primary site	Squamous cell epithelioma
7 M 57	15 mo.	12 mo.	Erosion body T-11; small mass in right upper chest; erosion 1st, 7th, 11th ribs	Loss of weight; constipation; hard nodule in prostate	T-9, T-12	?	Unimproved	Died 4 mo. postoperatively; no autopsy	Adenocarcinoma
8 M 68	3½ mo.	2 wk.	Erosion body T-4 vertebra; chest normal	None	T-2, T-5	?	Relief of pain; neurologic condition unimproved	Died 3 wk. postoperatively; no autopsy	Squamous cell epithelioma
9 M 43	4 mo.	1 wk.	Erosion pedicles T-5 and beginning collapse of body of T-5; chest normal	15 lb. loss of weight	T-5, T-6	Primary carcinoma of lung demonstrated by roentgenogram 3 mo. postoperatively	Relief of pain; return of sensation; minimal return motor power to date	Still alive 6 mo. postoperatively	Adenocarcinoma

TABLE 3.—*Myeloma (13 per Cent)*

Case No.	Age, Yr.	Sex	Duration of Root Irritation	Duration of Cord Compression	Roentgenographic Findings	Operative Results	Final Result	Other Areas Involved
10	64	M	2 wk.	1 wk.	Erosion pedicle T-4, T-5	Unimproved	Death 2 wk. postoperatively (pulmonary edema)	Not fully studied
11	52	M	6 wk.	2 days	Erosion laminas and spine T-6	Unimproved	Death 10 wk. postoperatively (infection)	Not fully studied
12	43	M	None	8 days	Erosion body T-10	Unimproved	Died 14 mo. postoperatively	(Necropsy) ribs; tibias; femorals
13	43	M	None	1 mo.	Erosion bodies C-2, 3 and 4	Prononced recovery of function for 1 year	Sudden death 1 yr. postoperatively	Cranial vault
14	58	F	None	3 mo.	Erosion transverse process T-7	Paraplegia; improved for 4 mo.; then recurrence	Still alive 1 yr. postoperatively but paraplegic	Right ileum; right humerus; left fibula
15	53	M	2 yr.	3 days	Normal spine and chest; myelographic block C-6	Unimproved	Died 2d postoperative day (respiratory failure)	Not fully studied
16	65	M	11 mo.	3½ mo.	Erosion body of T-7 vertebra	Motor power of legs recovered but insufficient to walk	Died 3 mo. postoperatively	None found

It is to be emphasized that these reported cases are only a small percentage of the cases of spinal metastases seen in this hospital. It is the policy in this clinic not to operate on metastatic tumors of the spine with cord compression that cord symptoms may well be due to vascular involvement as well as to direct compression.[1]

1. Elsberg, C.: Surgical Diseases of Spinal Cord, New York, Paul B. Hoeber, Inc., 1941, p. 499.

Operation was indicated in this group of 9 cases by the evidence of acute cord compression and the failure to demonstrate a primary lesion. Preoperative study was limited to complete history, physical examination and roentgen ray examination of the chest. The effects of the cord compression were generally unrelieved by operation, but the pain was alleviated in the majority of cases by the decompression afforded the spinal roots.

The tumors grossly were all extremely friable and encircled the dura both anteriorly and posteriorly. The laminas and the spines were always more extensively involved than the roentgen ray picture would lead one to believe. Microscopically the tissue was easily identified, although in several cases necrosis was so pronounced that histologic diagnosis rested on relatively small intact portions about the periphery of the lesion. Five of the lesions were adenocarcinomas, two were squamous cell epitheliomas and two were undifferentiated.

MYELOMAS

The lesions in this series that proved to be myelomas were associated with a uniform clinical picture. The patients were in the fifth to seventh decades of life, and all complained of an abrupt onset of symptoms of cord compression (three days to three months). There was roentgen evidence of vertebral erosion, usually in the thoracic region, and all patients had complete spinal subarachnoid block when tested by the Queckenstedt maneuver and/or by myelography after injection of iodized poppyseed oil (table 3). Six of the seven myelomas occurred in men. The acute onset of cord compression, preceded perhaps by a few months' history of localized root pain, was the first evidence of this usually widespread disease. In many instances, the exigencies of the acute cord compression compelled operation before complete roentgenologic studies of the skeletal system had been made. However, in the only 2 patients completely studied preoperatively (cases 12 and 15), the vertebral lesion causing the compression was an isolated one. One of these patients died three months postoperatively, without evidence of other involvement (case 15), but the other showed roentgenographic evidence of rib involvement four months after operation (case 12). Three patients were not sufficiently studied at any time prior to or after death to allow us to state whether the lesion of the vertebra was solitary or not. In the remaining 2 cases, other scattered lesions were demonstrated before the patients were discharged from the hospital. Alterations in the serum proteins and presence of Bence-Jones protein in the urine were not observed in the 3 cases in which appropriate laboratory examinations were done (cases 11, 12 and 14).

The epidural mass found at operation was usually described as extremely vascular and ringing the dural sac. However, in 2 instances the lesion was entirely anterior to the dura, the dural sac and cord knuckling over the mass. The tumors were composed of closely packed masses of cells which resembled plasma cells, although varying degrees of pleomorphism were observed. The resemblance to plasma cells was always sufficiently pronounced for ready identification. As a group these patients succumbed rapidly, the longest survival being fourteen months. One patient is still alive, having survived operation for one year.

The age and sex incidence in our small group is in accord with that noted in the literature.[2] The vertebrae are among the more commonly involved bones (Ewing [3] and Geschickter and Copeland [4]). Denkes and Brock [5] emphasized the frequency of neurologic signs and called attention to a group of patients who presented paraplegia as an initial symptom. According to these authors, the thoracic vertebrae are the ones most frequently involved. Davison and Balser [6] have reported 6 cases in which there were spinal involvement and cord compression.

Willis [7] has emphasized the rarity of solitary myelomas as compared with multiple lesions. He stated that of those which appear solitary when they first come under observation a number will subsequently become multiple, usually within the first year. Three of our patients are known to have multiple lesions. We cannot be certain of the solitary nature of the myeloma in the other 4 cases because clinical study was incomplete. Furthermore, Sproul [8] has pointed out

2. Atkinson, F. R. B.: Multiple Myelomata, M. Press **195**:312, 1937.

3. Ewing, J.: Neoplastic Diseases, ed. 4, Philadelphia, W. B. Saunders Company, 1940, p. 328.

4. Geschickter, C. F., and Copeland, M. M.: Tumors of Bone, New York, American Journal of Cancer, 1936, pp. 448-449.

5. Denkes, P. G., and Brock, S.: The Generalized and Vertebral Forms of Myeloma: Their Cerebral and Spinal Complications, Brain **57**:291, 1934.

6. Davison, C., and Balser, B. H.: Myeloma and Its Neural Complications, Arch. Surg. **35**:913 (Nov.) 1937.

7. Willis, R. A.: Solitary Plasmocytoma of Bone, J. Path. & Bact. **53**:77, 1941.

8. Sproul, E. E.: Multiple Myeloma, in Nelson's Loose-Leaf Living Medicine, New York, Thomas Nelson & Sons, 1941, vol. 4, pp. 91A-91GG.

the fact that widespread diffuse osseous involvement may occur without producing roentgenologically demonstrable changes.

NEUROBLASTOMAS

In this series of epidural lesions producing spinal cord compression there are six tumors which we have classified as neuroblastomas (sympathicoblastomas). Three of these occurred in patients between the ages of 9 and 12; the other patients were 6 months, 22 years and 67 years of age, respectively (table 4). In the cases of the 2 older patients, surgical treatment in this hospital was preceded by five and six months' histories of pain. Details of the history of the 6 month old infant are of course unknown, but in the 3 other cases the onset was rapid, there being in each case a history of pain of less than one month's duration and symptoms of cord compression of two to fourteen days' duration.

In 2 cases there was roentgenographic evidence of vertebral involvement, and postoperatively clinical or roentgen evidence was found suggesting a retroperitoneal mass in 4 cases and a posterior mediastinal tumor in 1 case. In all these cases, however, it was the neurologic symptoms produced by the epidural growth which caused the patient to seek medical attention and which dominated the clinical picture throughout.

At operation, there were no gross diagnostic features. In 5 of the 6 cases, the tumor was described as being red or bluish red and vascular. In 1 instance the vascularity was so pronounced as to lead to an operative diagnosis of hemangioma. The tumor lay anterior to the dura in 1 case, but in the others it surrounded the dura completely, extending the length of from one to four vertebrae. The dura was penetrated in 2 instances. In only 1 case did the tumor involve the upper thoracic portion of the spine, the remainder occurring in the lower dorsal or the upper lumbar region. In 3 cases the surrounding tissues, in particular the paravertebral muscles, were infiltrated by the neoplasm. In 2 cases there appeared foci of softening in the tumor, which led to the operative diagnosis of abscess. Only the 6 month old infant has done well postoperatively. One year after operation there has been some neurologic improvement and the mediastinal mass is somewhat smaller. No definitive treatment was given because the thoracic lesion when first discovered seemed too extensive to warrant expectation of any benefit from irradiation therapy. The other 5 patients are dead, 4 dying of infection, primarily of the urinary

TABLE 4.—*Neuroblastoma (11.1 per Cent)*

Case No.	Age, Yr.	Sex	Duration of Pain	Duration of Cord Compression	Roentgenogram of Spine	Extraspinal Tumor	Operative Findings	Results	Histologic Comment
17	22	M	5 mo.	2 mo.	Normal	None demonstrated	T-12 to L-4; dark red, vascular tissue completely surrounding dura	Died 6 mo. postoperatively of urinary and systemic infection after some neurologic improvement; no postmortem examination	Many large cells; no neurofibrils
18	11	F	1 mo.	3 days	Moth-eaten spinous processes and laminas T-12 to L-1	Autopsy demonstrated retroperitoneal mass invading epidural space metastases to pleura, lymph nodes, lung, kidney and ovary	Paravertebral muscles infiltrated; epidural space filled with necrotic tissue T-12 to L-2; intradural tissues uninvolved	Died 2½ mo. postoperatively of widespread infection and metastases	Little connective tissue; much necrosis; many mitoses; no neurofibrils
19	9	M	3 wk.	2 wk.	Normal	Retroperitoneal tumor continuous with epidural mass at necropsy	Red, vascular epidural mass T-11 to L-2	Died 2 wk. postoperatively of pyelitis and generalized infection	No neurofibrils; no large cells; many mitoses
20	12	M	3 wk.	2 days	Normal	Retroperitoneal tumor extending into epidural space through intravertebral canal of low thoracic region at necropsy	Reddish, granular tissue ringing the dura T-11	Died of widespread metastases 11 mo. postoperatively	Many large cells; no neurofibrils
21	6 mo.	F	?	6 wk. ?	Normal	Roentgenologic evidence of paravertebral thoracic mass	Extremely vascular bluish mass anterior to dura T-4, T-6	Well 1 yr. postoperatively; definite neurologic improvement; thoracic mass smaller without roentgen ray therapy	Occasional neurofibrils; occasional pseudorosettes; much calcific material
22	67	M	6 mo.	1 mo.	Density of body of 11th dorsal vertebra	Both kidneys displaced laterally; upper left ileopsoas shadow indistinct on intravenous urogram	Greenish, nonvascular tumor invading paravertebral muscles and filling epidural space T-8 to T-12	Died 5½ mo. postoperatively of urinary infection and progressive debility; no postmortem examination	No neurofibrils; no rosettes; no large cells

tract, and 1 dying with widespread metastases to the abdominal, thoracic and cervical lymph nodes and to the meninges at the base of the brain and of the spinal cord. The retroperitoneal organs were all encased in a widespread tumor which extended through the intervertebral canals into the epidural space. Two other cases came to autopsy [9] in 1 the abdominal viscera were described as being embedded in a huge tumor mass. The left adrenal gland could not be identified, and it therefore seems likely that the tumor arose there and completely destroyed it. In the other case studied at autopsy there was a retroperitoneal mass in continuity with the epidural lesion. The postoperative survival periods in the 5 cases varied from two weeks to eleven months.

There was some variation in the histologic appearance of these tumors (fig. 1). The basic structure was that of solid cords or small nests of tumor cells separated by usually delicate fibrous bands. The cells were uniformly rather small, with scanty cytoplasm, the latter often not discernible at all. The nuclei varied considerably in shape, being most frequently round or oval. They were hyperchromatic and often apparently solid. Silver stains demonstrated delicate reticulin fibers of variable number and distribution; at times, but not consistently, they appeared between the individual cells.

In 2 of the 6 cases in this group the tumors included many cells different from those described. They had more cytoplasm and nuclei in which the chromatin material was scattered in clumps. These appear to us to correspond to the "sympathoblasts" described by Rix and Geschickter [10] as distinguished from the less differentiated sympathogonia. In three of our tumors some of the cells were elongated and had indistinct and poorly formed cytoplasmic processes. In only 1 case was there any suggestion of pseudorosette formation and this appeared to be the result of degenerative changes. Cajal gold impregnations were not attempted, but the Bodian stain demonstrated a few neurites in one tumor. Our cases varied considerably in regard to the amount of stroma associated with the neoplasm. One specimen showed many tiny foci of calcification, and in another many foam cells were seen in association with extensive hemorrhage and necrosis. In the latter case the patient had received preoperative irradiation, with, incidentally, real, although temporary, benefit.

There is some question as to the accuracy of the classification of these six tumors as neuroblastomas. The difficulties of distinguishing neuroblastomas from Ewing's tumors on the basis of their histologic appearance is well known and has recently been reemphasized by Stout.[11] Barden [12] has pointed out the impossibility of making a differential diagnosis on grounds other than histologic. Willis [13] has expressed the opinion that the so-called Ewing's tumor of bone is not an entity but is rather a metastasis from an occult neuroblastoma. In only 1 of our cases did the preoperative clinical findings suggest that the neoplastic process might have had its origin in the bone. There was evidence in all the other cases, obtained at autopsy in 3, which indicated that the tumor probably invaded the epidural space from without, either from the retroperitoneal region or from the posterior mediastinum, both favored sites for neuroblastomas. In 1 case the primary retroperitoneal tumor appeared to arise in and destroy one adrenal gland. Rix and Geschickter,[10] in studying a series of tumors of the spine, concluded that neoplasms of the type under discussion were more properly classified as neuroblastomas, although the possibility of their being Ewing's tumors could not always be ruled out. On the basis of our material, we are in agreement with their conclusion.

The tumors of this group fit a consistent pattern; they commonly arise paravertebrally in the dorsolumbar region, usually in children, invading the spinal column and epidural space and producing cord compression. They may be sensitive to irradiation but nevertheless pursue a fatal course. This is in close agreement with the experience of Rix and Geschickter, who described 12 such cases. They explained the not infrequent intraspinal location of neuroblastomas on the basis of origin from rests of cells formed when the neuroblasts migrate peripherally from the primitive neural tube. It is possible that the tumors in our group had a similar origin, although, as previously noted, it seems more likely that they invaded the epidural space from without.

9. The autopsy in the first of these cases was performed by Dr. C. R. Tuthill, of St. Joseph's Hospital in Lancaster, Pa., who has sent us a report of her findings and permitted us to study the sections.

10. Rix, R. R., and Geschickter, C. F.: Tumors of the Spine with a Consideration of Ewing's Sarcoma, Arch. Surg. **36**:899 (June) 1938.

11. Stout, A. P.: A Discussion of the Pathology and Histogenesis of Ewing's Tumor of Bone Marrow, Am. J. Roentgenol. **50**:334, 1943.

12. Barden, R. P.: The Similarity of Clinical and Roentgen Findings in Children with Ewing's Sarcoma (Endothelial Myeloma) and Sympathetic Neuroblastoma, Am. J. Roentgenol. **50**:575, 1943.

13. Willis, R. A.: Metastatic Neuroblastoma in Bone Presenting Ewing's Syndrome, with a Discussion of "Ewing's Sarcoma," Am. J. Path. **16**:317, 1940.

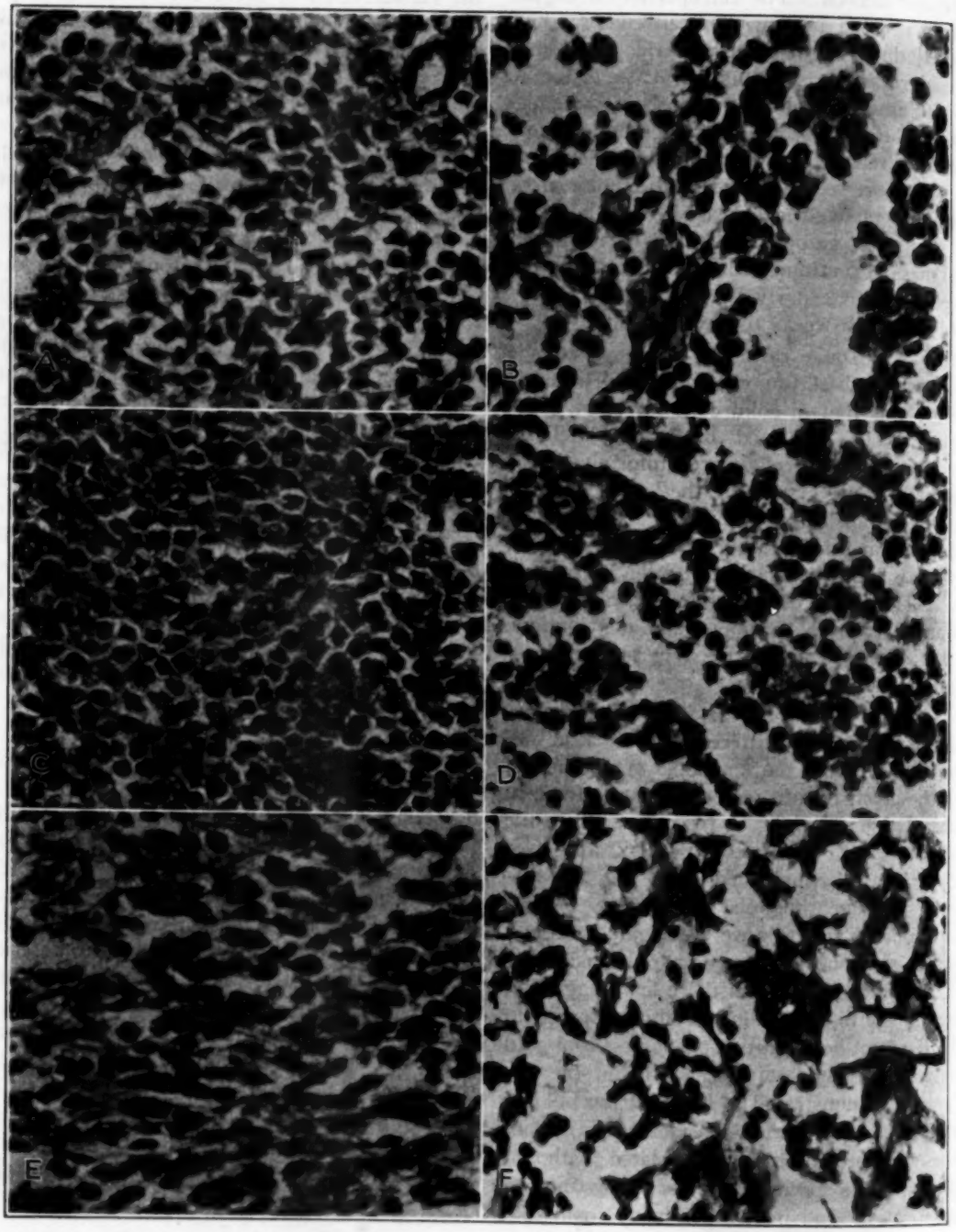

Fig. 1.—Neuroblastoma of the spinal epidural space. *A* to *F* are from cases 17 to 22 respectively. Variations in compactness and cellularity are evident, although the cells are of the same order of magnitude and are generally similar. *E* (case 21) showed many small calcific deposits. This was the only tumor in which pseudorosettes were seen and in which neurofibrils were demonstrated in Bodian preparations. Hematoxylin and eosin; × 489.

GIANT CELL TUMOR OF BONE

The clinical picture presented in the 3 cases in this group was remarkably consistent. The patients were in the second decade of life, and the onset of cord compression was relatively abrupt (table 5). Pain in the back had been present for a matter of months, but the duration of cord compression was given as six weeks, four weeks and two days, respectively, and progressed rapidly. The lesions were all thoracic in location, and the roentgenograms showed erosion of the spines, pedicles and/or bodies of the vertebrae. There was no history of trauma. The occurrence of such lesions in the vertebrae of young persons is the subject of a number of reports in the literature, as is the relatively rapid progress of cord compression, which is seen to some degree in about 50 per cent of cases. The site, however, is not limited to the dorsal area but is well distributed throughout the entire length of the vertebral column.

TABLE 5.—*Giant Cell Tumor of Bone (5.6 per Cent)*

Case No.	Age, Yr.	Sex	Duration of Pain	Duration of Cord Compression	Roentgenogram of Spine	Location of Epidural Lesion	Roentgen Ray Therapy	Result
23	10	F	2 mo.	1 mo.	Erosion vertebral body and facets T-8	T-8	Two courses, 1 wk. and 3 mo. postoperatively (amount of roentgens not known)	Well, 9 yr.
24	20	F	4 mo.	2 days	Erosion spines and pedicles T-4 and T-5	T-3 to T-5	2,100 r 2 mo. postoperatively (in one course over 1 mo. period)	Well, 2 yr.
25	15	M	9 mo.	6 wk.	Erosion pedicles T-6 and T-7	T-7	Incomplete course of 200 r 2 weeks postoperatively	Well, 3½ yr.

The operative findings were similar in each case. An encapsulated epidural tumor mass was found, its bulk posterior to the dural sac, but with a tendency to extend forward about the dura in the lateral gutters of the intravertebral canal. Connection with the bony defects seen on roentgenographic examination was not remarked on. On section, red soft granular but not friable tissue was seen to lie between fibrous bands.

The tumors were composed of giant cells scattered in varying numbers in a vascular and cellular stroma (fig. 2). The giant cells were of the type commonly seen in giant cell tumors of bone, generally with numerous small, ovoid nuclei. The stromal cells were of moderate size and either rounded or spindle shaped. In 1 of our cases there were extensive areas of hemorrhage and the giant cells were relatively infrequent. The sections of two of the lesions showed extensive new bone formation, a feature of the vertebral giant cell tumor emphasized by Dean Lewis.[14] The frequency with which spindle cells predominate in the giant cell tumors of the small bones, especially the vertebrae, has been pointed out by Geschickter and Copeland,[15] who expressed the opinion that it, along with the new bone formation, is evidence of a healing reaction. Although not conspicuous, this feature is seen in our cases. These variations of the giant cell tumor of small bones from the typical epiphysial giant cell tumor—the frequent finding of new bone formation, the predominance of spindle cells and the age distribution—all suggest a relationship to bone cyst. Our cases are representative of the usual age distribution of vertebral giant cell tumors, whereas giant cell tumors of other situations commonly occur at a later age.[16] Most authors are agreed that the giant cell tumor of the spine is benign,[17] and Geschickter and Copeland stated [15] that it has even less tendency to recur than do giant cell tumors in other locations. All 3 of our patients are well after surgical curettage and postoperative irradiation after two, three and a half and nine years respectively.

MISCELLANEOUS EPIDURAL TUMORS

Lymphosarcoma.—There were only 2 cases of lymphosarcomas in our series, although several other cases had been previously so classified

14. Lewis, D.: Primary Giant Cell Tumors of the Vertebrae, J.A.M.A. **83**:1224 (Oct. 18) 1924.

15. Geschickter and Copeland,[4] pp. 333-341.

16. Willard, deF., and Nicholson, J. T.: Giant Cell Tumor of the Cervical Spine, Ann. Surg. **107**:298, 1938.

17. Santos, J. V.: Giant Cell Tumor of Spine, Ann. Surg. **91**:37, 1930. Grieve, W. E.: Giant Cell Tumor of Vertebrae, Northwest Med. **33**:81, 1934. MacFarlane, J. A., and Linell, E. A.: Benign Giant-Cell Tumor of Third Cervical Vertebra, Brit. J. Surg. **21**:513, 1934. Murphy, G. W.: Giant Cell Tumor of Spine, Am. J. Roentgenol. **34**:386, 1935. Duncan, G. A., and Ferguson, A. B.: Benign Giant Cell Tumor of the Fourth Lumbar Vertebra, J. Bone & Joint Surg. **18**: 769, 1936. Giant Cell Tumor of Spine, Cabot Case 23081, New England J. Med. **216**:348, 1937.

(table 6). In both instances symptoms of spinal root involvement and cord compression were the first manifestations of this disease. However, this mode of onset of lymphosarcoma is not rare and has been commented on frequently.[18] The 2 patients were 35 and 21 years respectively, and their root symptoms were present for less than a year. The cord compression manifested itself abruptly in 1 instance, becoming complete in a period of a few days, while in the second case the paraplegia gradually progressed over a period of four months. Postoperatively, a generalized lymphadenopathy became manifest in both patients.

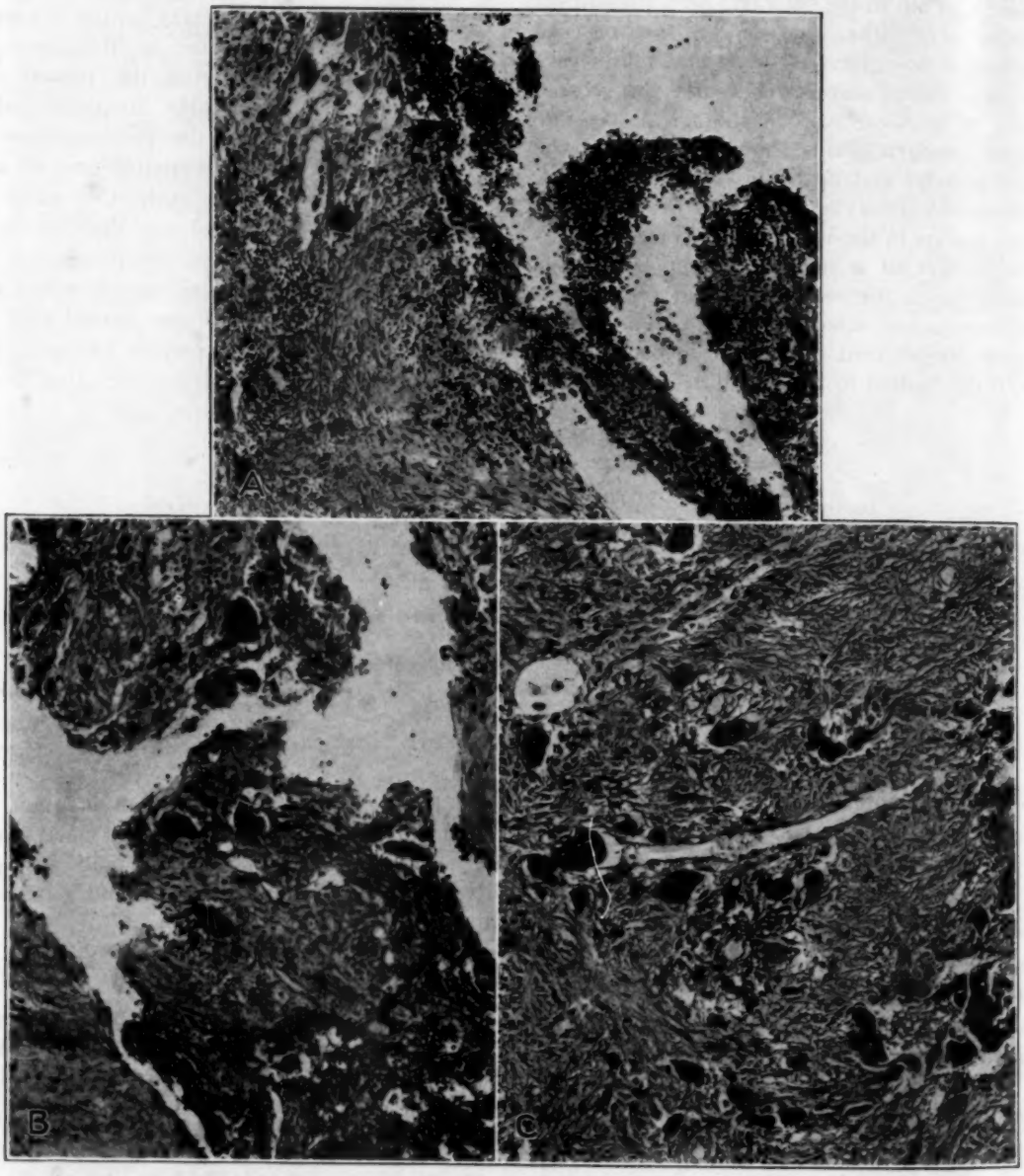

Fig. 2.—Giant cell tumor of vertebra invading epidural space. *A* to *C* are from cases 23 to 25, respectively. *A* (case 23) and *C* (case 25) show abundant collagen with many spindle-shaped cells, and in *C* evidence of bone destruction is seen. Hematoxylin and eosin; × 118.

The epidural masses encountered at operation were unencapsulated, moderately firm and rather vascular, and the dura was not penetrated in

18. Paullin, J. E.: Central Nervous System Manifestations of Lymphogranuloma, Tr. A. Am. Physicians **46**: 252, 1931. Davison, C., and Michaels, J. J.: Lymphosarcoma, with Involvement of Central Nervous System, Arch. Int. Med. **45**:908 (June) 1930. Browder, J., and de Veer, J. A.: Lymphomatoid Diseases Involving the Spinal Epidural Space, Arch. Neurol. & Psychiat. **41**:328 (Feb.) 1939.

either case. Histologic examination of both lesions showed diffuse sheets of cells slightly larger and more irregular than normal adult lymphocytes. Moderate numbers of cells, two to three times this size, were intermingled, especially in the case of the 35 year old man. There was little supporting stroma.

In the case of the 21 year old woman, an essentially similar picture was seen in biopsy sections of a large cervical mass. We have classified both lesions as lymphosarcomas of the lymphocytic cell type. Both patients have had intensive irradiation. They are able to get about with canes and are in good general physical condition sixteen and ten months respectively after their operative decompressions.

Other cases previously reported follow a pattern similar to that of these 2 cases.[18] Lymphosarcoma with its first manifestations, those of spinal root or cord involvement, is a lesion which occurs in young adults and presents a progressive picture of moderate rapidity, the usual course prior to operation being four to eight months.

Tumors of Adipose Tissue.—Among the uncommon lesions in this series were one lipoma and one liposarcoma. Fatty tumors form a small group in the larger series of spinal cord tumors previously reported.[19] They are usually extradural in location, a situation in which adipose tissue normally occurs. The benign lipoma in

TABLE 6.—*Miscellaneous Epidural Tumors: Lymphosarcoma (3.7 per Cent)*

Case; Sex; Age, Yr.	Duration of Pain	Duration of Cord Compression	Roentgenogram of Spine	Operative Findings	Result	Comment
				Lymphosarcoma (3.7 per cent)		
26 M 35	6 mo.	1 wk.	Normal	Extradural vascular mass infiltrating paravertebral muscles T-4, T-7	Able to walk with cane; sphincter function regained (16 mo. postoperatively)	Generalized lymphadenopathy 8 mo. postoperatively controlled by roentgen ray therapy
27 F 21	10 mo.	4 mo.	Normal	Firm, whitish, fibrous, unencapsulated extradural mass, infiltrating paravertebral muscles L-1 to L-4	Able to walk; sphincter function regained (16 mo. postoperatively)	Generalized lymphadenopathy 3 mo. postoperatively controlled by roentgen ray therapy
				Tumors of Adipose Tissue (3.7 per cent)		
28 F 45	0	6 yr.	Normal	Extradural brownish red mass T-5 to T-8	Complete recovery; died 6 yr. postoperatively of coronary occlusion	Lipoma
29 M 42	1 mo.	24 hr.	Destruction body T-8 vertebra and disk between T-8 and T-9	Reddish, beefy, vascular mass anterior to dura, level T-8 vertebra	Unimproved; 6 mo. postoperatively contact lost	Liposarcoma
				Blood Vessel Tumors (3.7 per cent)		
30 F 54	0	1 yr.	Erosion T-4 vertebra; appearance suggestive of angioma	Red, encapsulated, vascular extradural tumor T-3 and T-4	Immediate improvement; completely well 3 yr. postoperatively	Numerous blood-filled cavernous spaces; small amount of adipose tissue included in tumor; diagnosis: cavernous hemangioma
31 M 43	5 mo.	1 mo.	Destructive lesion T-3 vertebra	Friable, soft, red, vascular, extradural tumor T-2, T-4	Unimproved by operation; died 5 mo. postoperatively; no necropsy	Tumor cells outside reticulin network about small capillaries and endothelial sprouts; diagnosis: malignant hemangiopericytoma
				Acute Monocytic Leukemia (1.9 per cent)		
32 F 18	5 wk.	2 wk.	Normal	Increased amount of yellowish green epidural tissue C-7 to T-2	Unimproved by operation; died 9th postoperative day	Generalized lymphadenopathy; moderate swelling of gums; high fever; typical blood picture of acute monocytic leukemia
				Neurilemmoma (1.9 per cent)		
33 F 52	7 mo.	7 mo.	Widening of intervertebral foramen C-2	Spinal cord pushed to left at level C-2 by white, homogeneous soft mass	After temporary improvement, death 9 mo. postoperatively (urinary sepsis)	Tumor incompletely removed
				Unclassified (3.7 per cent)		
34 F 46	4 yr.	1 yr.	Rarefying lesion bodies of vertebrae C-2 to C-6; hemangioma ?; sarcoma ?; metastatic carcinoma ?	C-2 to C-6; mass seemed to invade or come from vertebral bodies	Complete recovery; died of rectosigmoid carcinoma 11½ yr. postoperatively	Hemangioma ??; no necropsy performed
35 M 20	3 mo.	2 wk.	Normal	Encapsulated purplish mass at level T-6	Unimproved; death with metastases 2 yr. postoperatively	Malignant neurilemmoma ??; autopsy performed

19. (*a*) Spurling, R. G., and Mayfield, F. H.: Neoplasms of the Spinal Cord, J. A. M. A. **107**:924 (Sept. 19) 1936. (*b*) Rasmussen, T. B.; Kernohan, J. W., and Adson, A. W.: Pathologic Classification with Surgical Consideration of Intraspinal Tumors, Ann. Surg. **111**: 513, 1940. (*c*) Elsberg, C. A.: Some Pathological Features of the Primary and Secondary Extramedullary Tumors of the Spinal Cord, J. Mt. Sinai Hosp. **7**:247, 1941. (*d*) Ehni, G., and Love, J. G.: Intraspinal Lipomas, Arch. Neurol. & Psychiat. **53**:1 (Jan.) 1945.

our series was a brownish red, well demarcated mass lying in the posterior extradural space of the upper thoracic portion of the spine of a 45 year old woman. She had never had symptoms suggesting root irritation but did present a picture of a slowly progressive paraparesis of six years' duration. She recovered completely after removal of the tumor, returning to full time employment, only to die abruptly six years postoperatively of a myocardial infarcation. Microscopic examination revealed a lesion composed of adult fat cells separated by much connective tissue. In the peripheral part of the tumor were many small, distended and thin-walled blood vessels, which accounted for the red color noted at operation. Ehni [19d] has commented on the frequency with which extradural lipomas are associated with angiomatous characteristics and considered this association as one indication of the common embryologic origin of endothelium and adipose tissue.

In the case classified as one of liposarcoma there was a much more explosive course. The patient, a 42 year old man, complained of root pain for about one month and became completely paraplegic in a period of twenty-four hours. Roentgenologic examination revealed erosion of the body of the eighth thoracic vertebra. Operation disclosed a beefy red, vascular mass anterior to the dura at this level. Six months after operation the man was still unimproved. He has not been heard from since (four years ago).

On histologic examination (fig. 3), some portions of the tumor were seen to be composed of closely packed, rounded cells with abundant, finely vacuolated cytoplasm and round, more or less centrally placed nuclei. Occasionally these cells were rather large and multinucleated, but bizarre or monster forms were not a feature. Tissue of this type merged with other highly vascular areas consisting of readily identified fat cells, some adult, others differing from the adult cells only in having prominent nuclei and still others of embryonal appearance. The latter were usually stellate and occasionally contained cytoplasmic vacuoles. The supporting structure about the tumor cells was a scanty network of delicate reticulin fibers. This tumor appears to correspond to a mixture of what Stout [20] has classified as the myxoid and the round cell type of liposarcoma. He considered such mixed types of liposarcoma as definitely malignant and capable of metastasis. It is unfortunate that our patient was lost to follow-up after only six months.

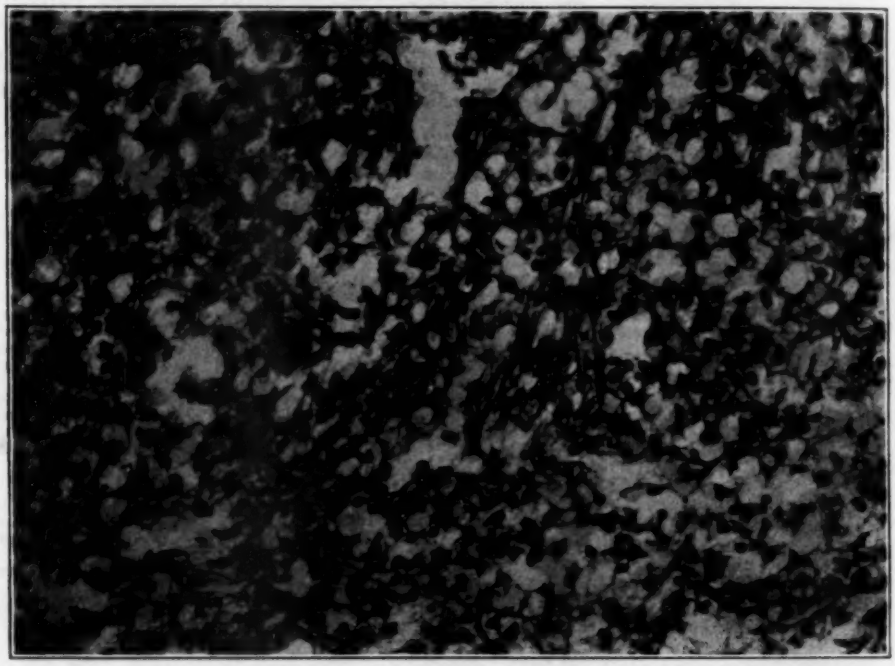

Fig. 3 (case 29).—Liposarcoma of spinal epidural space. Hematoxylin and eosin; × 320.

Blood Vessel Tumors.—The phenomenon of cord compression by vertebral hemangiomas has been the subject of frequent comment.[21] In our

20. Stout, A. P.: Liposarcoma — The Malignant Tumor of Lipoblasts, Ann. Surg. **119**:86, 1944.

21. Cornil, L., and Mosinger, H.: Sur les angiomes et telangiectasies intrarachidiens, Ann. d'anat. path. **9**: 955, 1932. Johnston, L. M.: Epidural Hemangioma with Compression of Spinal Cord, J.A.M.A. **110**:119 (Jan.

series, however, there is only 1 example of this lesion, although 1 of our unclassified cases may represent a second. The patient was a 54 year old spinster who had gradually progressive weakness of the lower limbs over a period of one year. She did not experience symptoms of root irritation at any time. A roentgenogram of the thoracic portion of the spine revealed erosion of the body of the fourth thoracic vertebra that was interpreted as typical of angioma. Operation revealed a bright red, encapsulated, extremely vascular extradural lesion measuring 3 by 1.5 by 2.5 cm. and weighing 2.5 Gm. Histologically, it was a characteristic cavernous hemangioma. After its removal the patient made a full recovery, and when last heard from, three years after operation, she was gainfully employed and her only residuum was occasional girdle-like pain.

We have observed one other extradural vascular tumor in this series. This was a metastatic tumor of an unusual type occurring in a 43 year old man who had complained for five months of pain in the back. He had had progressive weakness of the legs for one month. Roentgenologic study of the spine revealed a destructive lesion of the third thoracic vertebra. At operation the laminas of the second, third and fourth thoracic vertebrae were extremely friable and highly vascular, and the epidural space was filled with a red, soft, friable, vascular tumor. This man had been admitted to the hospital on eleven previous occasions, every time but one for study and treatment of disease conditions unrelated to the present complaints. However, two years before the onset of cord symptoms, he had been hospitalized for surgical removal of a tumor of the soft tissues of the thigh. This tumor never recurred locally. During convalescence from laminectomy a discrete pulsating mass became apparent over the sternum, and roentgen ray examination demonstrated involvement of the underlying bone. The patient's condition was not improved by operation, and he died five months later in another hospital. Autopsy was not performed.

The tumor was composed basically of small capillaries lined by normal-appearing endothelial cells and surrounded and supported by a dense network of collagen and reticulin fibers (fig. 4). The tumor cells, which were usually rounded or ovoid but occasionally elongated, were massed outside the reticulin fibers which immediately surrounded the vessels, an arrangement well demonstrated only by silver reticulin stains. In general, the vessels were so close together that the cells surrounding one vessel merged with those surrounding others. There was a moderate degree of cellular pleomorphism, and occasional mitotic figures were seen.

We were privileged to study the sections of the tumor removed from the thigh two and one-half years before. It was strikingly similar to that removed from the epidural space, but the fundamental structure was somewhat more readily apparent in the primary tumor. This structure, "basic composition of endothelium-lined capillaries or impervious endothelial sprouts surrounded by rounded cells with a supporting meshwork of reticulin fibers," is described by Stout and Murray [22] as characteristic of the tumor which they have labeled "Hemangiopericytoma." Most of the 9 tumors they reported on and the hemangiopericytoma of the omentum subsequently described by Stout and Cassel [23] were benign, but the group reported by Stout and Murray included one tumor which exhibited aggressive, infiltrative local growth and one example of a malignant metastasizing neoplasm (case 9). The latter tumor arose in the soft tissues of the thigh of a 34 year old Negro woman and seven years later (four years after excision) multiple metastases to the liver were demonstrated at laparotomy and verified by biopsy. Later roentgenographic evidence of metastases in two ribs developed, and she finally died three years after the demonstration of hepatic involvement. In addition to the features characteristic of hemangiopericytoma, her tumor showed areas where extensive fibrosis and hyalinization had taken place about the vessels, pushing aside the pericytes, which appeared atrophic. Some areas in the tumor observed by us closely resembled this picture.

We have classified our case as an instance of a malignant hemangiopericytoma, primary in the

8) 1938. Karshner, R. G.; Rand, C. W., and Reeves, D. L.: Epidural Hemangioma Associated with Hemangioma of the Vertebrae, Arch. Surg. **39**:942 (Dec.) 1939. Kelly, L. C.: Vertebral Hemangioma with Neurologic Symptoms, New York State J. Med. **40**: 1607, 1940. Turner, O. A., and Kernohan, J. W.: Vascular Malformations and Vascular Tumors Involving the Spinal Cord, Arch. Neurol. & Psychiat. **46**: 444 (Sept.) 1941. Ghormley, R. K., and Adson, A. W.: Hemangioma of Vertebrae, J. Bone & Joint Surg. **23**: 887, 1941. Ferber, L., and Lampe, I.: Hemangioma of Vertebra Associated with Compression of Cord, Arch. Neurol. & Psychiat. **47**:19 (Jan.) 1942. Blackford, L. M.: Hemangioma of Vertebra with Compression of Spinal Cord, J. A. M. A. **123**:144 (Sept. 18) 1943.

22. Stout, A. P., and Murray, M. R.: Hemangiopericytoma: A Vascular Tumor Featuring Zimmermann's Pericytes, Ann. Surg. **116**:26, 1942.

23. Stout, A. P., and Cassel, C.: Hemangiopericytoma of the Omentum, Surgery **13**:578, 1943.

soft tissues of the thigh. There is little doubt that the epidural lesion is a metastasis, and the same is probably true of the sternal mass which developed shortly before death.

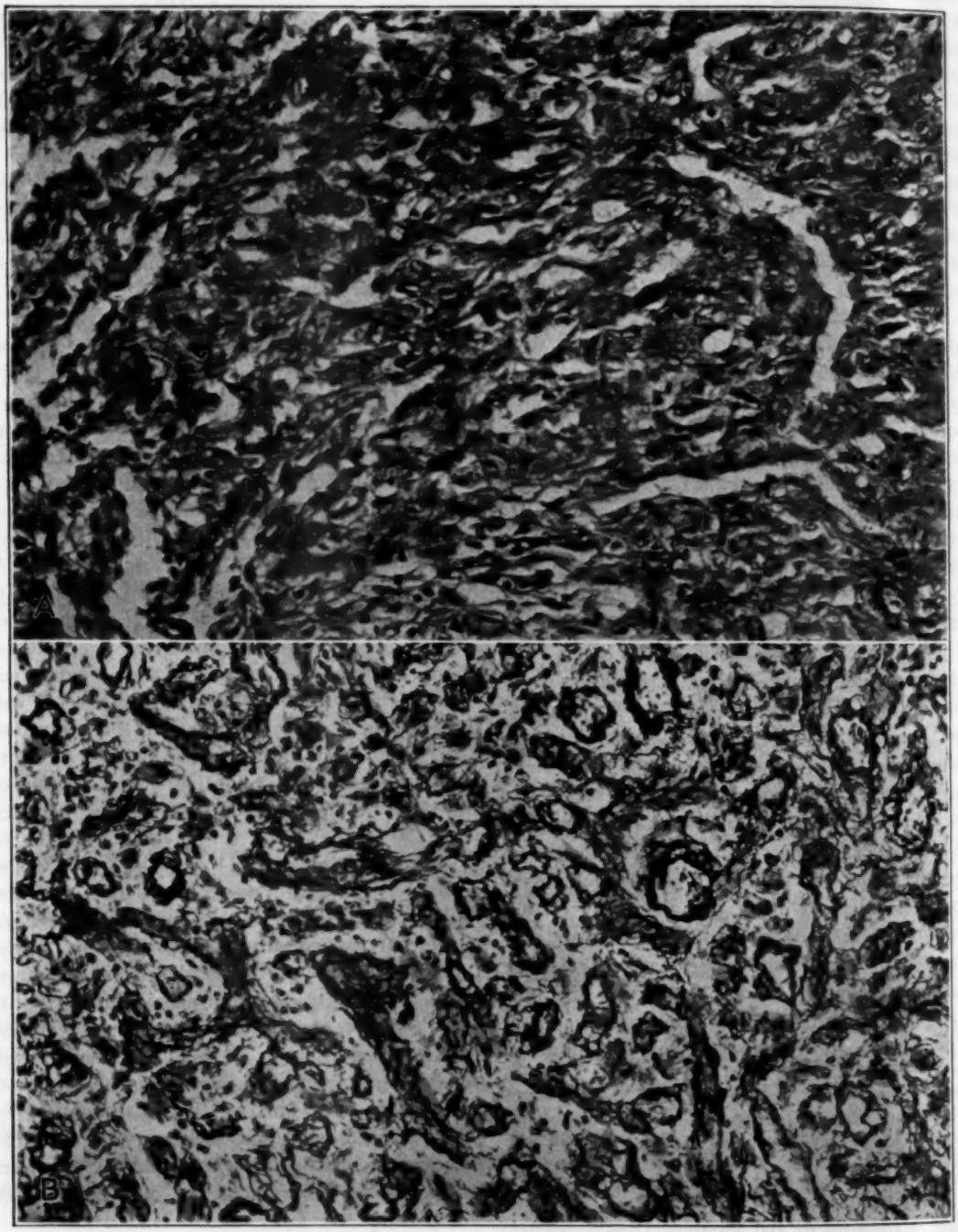

Fig. 4 (case 31).—Metastatic malignant hemangiopericytoma in spinal epidural space. Above, hematoxylin and eosin stain. Below, Laidlaw silver stain demonstrating the vascular pattern of the tumor. The tumor cells lie outside the reticulin sheaths of the vessels, which are lined by normal endothelia. × 306.

Leukemic Infiltration of Epidural Space.—An 18 year old girl was seized with severe root pains soon followed by a rapidly progressive quadriplegia, most pronounced in the lower extremities. She was admitted from another hospital as an emergency, although the diagnosis of acute monocytic leukemia had been made on the basis of blood smears. Generalized lymphadenopathy and high fever were present. There was a complete spinal fluid block as revealed by a Quecken-

stedt procedure, and the fluid had a high total protein content. A good sensory level was present at the first or second thoracic vertebra. In view of the rapidly progressing neurologic picture and in spite of the probable diagnosis of acute leukemia, it was thought that in view of the rarity of the syndrome of cord compression in leukemia, decompressive laminectomy was indicated on the chance that the spinal lesion might be of a type with a more favorable prognosis, such as an epidural abscess. The epidural fat was greatly hypertrophied in the area explored, the seventh cervical vertebra to the second thoracic vertebra; the cord itself appeared normal. Microscopic section of the tissue removed from the epidural space revealed a heavy infiltration of large rounded cells with single, often bean-shaped nuclei (fig. 5). They appeared identical with the cells seen in smears of the peripheral blood which were interpreted as immature cells of the monocyte series. The patient was unimproved by operation and died on the ninth postoperative day with hyperthermia.

The literature reveals this to be an extremely uncommon form of onset in leukemia. It appears, however, that the spinal cord symptoms seen in leukemic states are most commonly due to epidural infiltration.[24] In a brief survey of the literature, we encountered no reported cases of acute monocytic leukemia presenting the aforementioned syndrome.

Neurilemmoma. — Benign nerve sheath tumors (neurilemmoma, schwannoma, perineural fibroblastoma, neurinoma and neurofibroma) situated entirely outside the dural sac are not rare, though the majority have an intradural, extramedullary location. Wolf, in Elsberg's "Surgical Diseases of the Spinal Cord,"[25] reported ten of sixty-seven such tumors to be entirely extradural. However, we have encountered only one completely extradural neurilemmoma. This was in a 52 year old woman who had a history of root pains and cord compression of seven months' duration. Roentgent ray examination showed an enlargement of the intervertebral canal between the second and third cervical vertebrae. At operation the cord was seen to be pushed to the left at the level of the second cervical vertebra by an extradural mass anterior

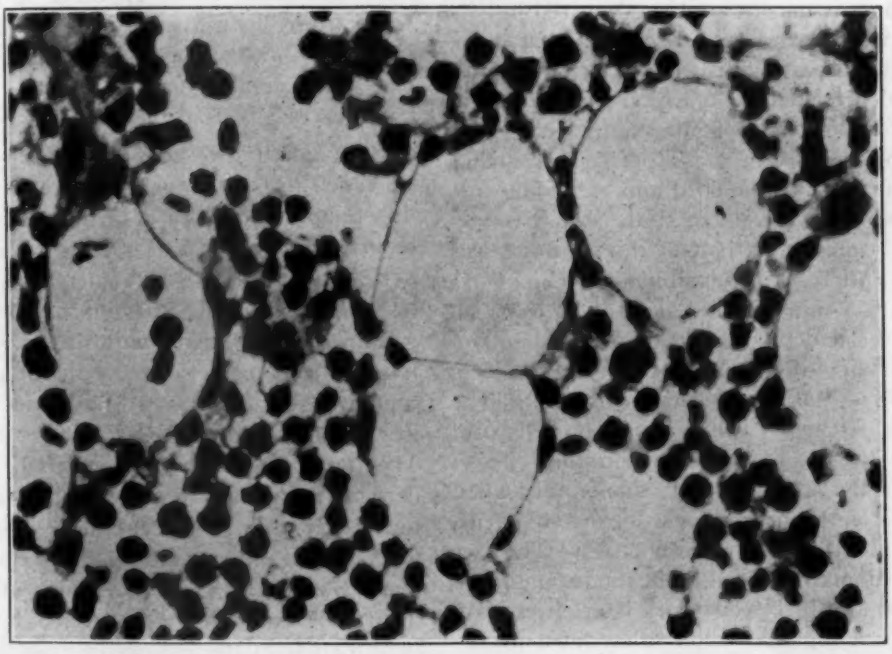

Fig. 5 (case 32).—Leukemic infiltration of spinal epidural space. Acute monocytic leukemia. Hematoxylin and eosin; × 700.

24. Critchley, M., and Greenfield, J. G.: Spinal Symptoms in Chloroma and Leukemia, Brain **53**:11, 1930. Reese, H. H., and Middleton, W. S.: Mechanical Compression of the Spinal Cord by Tumorous Leukemic Infiltration, J.A.M.A. **98**:212 (Jan. 16) 1932. Scalori, G., and Nobile, A: Leucemia sinfatica acuta con interessamento della tonsilla faringea, invasione della cavita cranica e compressione midollare da infiltrato epidurale, Riv. oto-neuro-oftal. **15**:265, 1938. Fried, B. M.: Leukemia and the Central Nervous System, Arch. Path. **2**:23 (July) 1926.

25. Wolf, A.: Pathology of Spinal Cord Tumors, in Elsberg, C.: Surgical Diseases of the Spinal Cord, New York, Paul B. Hoeber, Inc., 1941, p. 235.

and to the right of the cord. This tumor was only partially removed. Histologically it showed the "Antoni types A and B" tissue characteristic of the specific nerve sheath tumor, in addition to well marked nuclear palisading. This undoubtedly extended into and perhaps through the intervertebral canal as a "collar button." The patient was much improved for several months after operation but then had an abrupt and pronounced relapse with onset of quadriplegia. She was again operated on, and additional tumor tissue was removed but this did not improve her; she lingered for several months but finally succumbed to widespread sepsis. No postmortem examination was performed.

Unclassified Epidural Tumors.—The classification of two of the lesions in this group of extradural tumors is uncertain. One occurred in a 46 year old woman and gave rise to a right hemiparesis with a partial Brown-Séquard syndrome which had persisted for one year before the patient was subjected to laminectomy (case 34). Operation disclosed a mass of black pastelike material anterior to the cord and extending into the bodies of the second to sixth cervical vertebrae. Only about one half of this material was removed. Microscopic examination (fig. 6*A*) showed heavy fibrosis and deposition of small amounts of calcific material and large amounts of pigment having the appearance of hemosiderin and giving a positive reaction for iron. The tissue was not highly cellular, but the cells present were large and fusiform and their nuclei varied widely in size and shape. Rounded eosinophilic intranuclear inclusions were striking, but mitotic figures were not seen. The fact that the patient remained well almost until the time of her death, eleven years later, from carcinoma of the sigmoid colon rules out a malignant tumor. Since the patient received an unknown amount of irradiation treatment before laminectomy, it seems probable that the true nature of the lesion was masked by the reaction to irradiation. The heavy deposit of blood pigment suggests that the original vertebral lesion may have been a hemangioma, as had been suggested on the basis of roentgen ray studies.

The other unclassified lesion was a highly malignant tumor which occurred in a 20 year old man and produced a complete spastic paraplegia within two weeks of the onset of symptoms (case 35). Two years after laminectomy the patient died of extensive local recurrence and metastases to the skull, involving the orbits, dura and scalp, to the subcutaneous tissues overlying the lumbar and upper cervical portions of the spine and to the lung and the pleura. The tumor removed at laminectomy was a soft, purple, apparently encapsulated mass ringing the dura on three sides and extending into the transverse process of the sixth thoracic vertebra.

In most of the sections, including those prepared from the autopsy material, the tissue was poorly preserved. The tumor was composed of small elongated cells sometimes arranged in interlacing bands. Much of the tumor, however, was loose textured and hemorrhagic, and the individual cells were widely separated and without definite relationship to one another. The metastases were morphologically similar to the primary extradural tumor, but in a section from a pulmonary metastasis an area was seen in which bands of tumor tissue appeared to radiate outward from blood vessels and in which nuclear palisading was unmistakable (fig. 6*B*). This one small area suggested that the tumor had taken its origin from the sheath of Schwann.

Although this is admittedly meager evidence on which to base a diagnosis, we have classified this tumor tentatively as a malignant neurilemmoma. Although Ehrlich and Martin [26] referred to several cases in which there was recurrence or infiltration locally, they stated that no case of genuine neurilemmoma with metastases has been recorded in the literature, with the possible exception of the fourth case in a series of cases of nerve tumors reported by Cutler and Gross.[27] The tumor in this case arose from the median nerve of a 56 year old man and had been present for twenty years. A year after excision the patient died of extensive local recurrence and pulmonary metastases. The nerve sheath origin of the tumor could not be detected by histologic examination of the recurrence, but the author's description of the original median nerve tumor coincides with the typical neurilemmoma (Stout [28]) except for a greater degree of pleomorphism than is usually seen.

SPINAL EXTRADURAL CYST

Spinal extradural cysts have only recently been described. However, since the first report of

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26. Ehrlich, H. E., and Martin, H: Schwannomas (Neurilemomas) in the Head and Neck, Surg., Gynec. & Obst. **76**:577, 1943.

27. Cutler, E. C., and Gross, R. E.: Neurofibroma and Neurofibrosarcoma of the Peripheral Nerves Unassociated with Recklinghausen's Disease, Arch. Surg. **33**:733 (Nov.) 1936.

28. Stout, A. P.: Peripheral Manifestations of the Specific Nerve Sheath Tumor (Neurilemoma), Am. J. Cancer **24**:751, 1935.

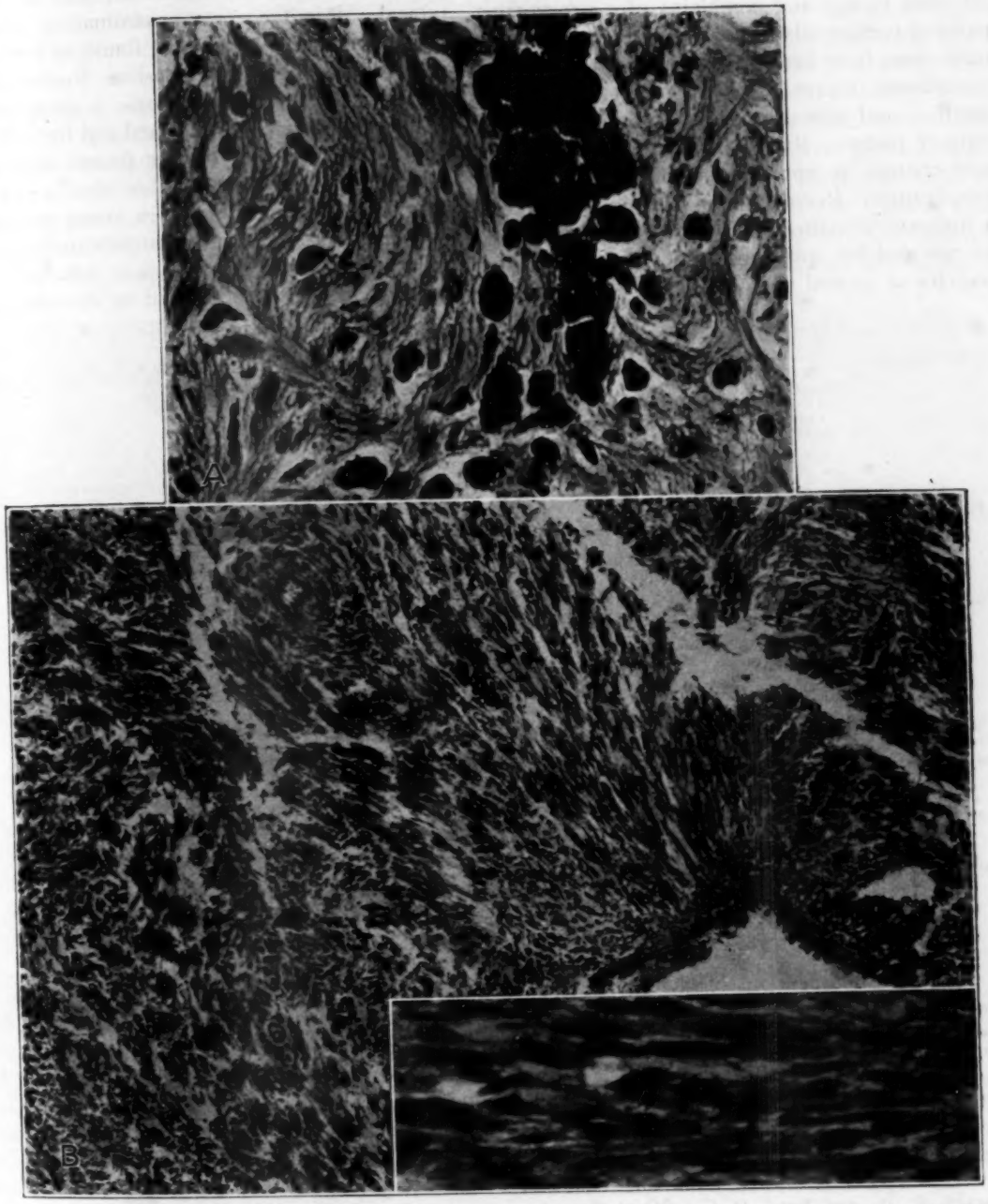

Fig. 6.—Unclassified tumors of spinal epidural space. *A* (above), case 34. Hemangioma? after irradiation. The large cells with occasional eosinophilic intranuclear inclusions can be seen, although hemosiderin deposition is the most conspicuous finding. Hematoxylin and eosin; × 260. *B* (below), case 35. Malignant neurilemmoma? The photomicrograph is of a metastatic nodule in the lung. The nuclear palisading is strongly suggestive of nerve sheath origin. Palisading was not seen elsewhere in numerous sections of both the primary tumor and the metastases. Hematoxylin and eosin; × 132. Inset shows detail. × 600.

cases, in 1934,[29] many reports have firmly established this lesion as a clinical and pathologic entity.[30] The patient is usually between 10 and 20 years of age and complains of a progressive painless paraparesis. In a few cases spontaneous remissions have been reported, only to have the paraparesis return and progress. Changes in position and vibratory sensation dominate the sensory picture. Rarely, if ever, is there a definite change in appreciation of either pain or temperature. Roentgen ray examination shows a fusiform dilatation of the intravertebral canal, as revealed by spreading and flattening of the pedicles of several adjacent vertebrae. A partial or complete subarachnoid block can be demonstrated by the Queckenstedt test. The histories of our patients fit well into this picture (table 7). One patient is older than those in previously reported cases, but her lesion was otherwise typical. Roentgen ray examination revealed changes identical with those found in previously reported instances of this lesion. Neither of our patients had a dorsal kyphosis, a change which has been associated by Cloward and Bucy [30e] with this lesion. In our younger patient a kyphosis developed postoperatively, but this is not rare after dorsal laminectomies in young persons.

Neither of the cysts communicated with the subarachnoid space. One was attached to a nerve root, but the other had no obvious attachments. The walls of both were composed of acellular collagenous tissue, which resembled dura mater. One was lined with low columnar cells resembling arachnoidal cells; the other had no specific cellular lining layer. One cyst contained clear, watery fluid; the other, in the older patient, contained thicker, more oily fluid. Both patients made rapid, complete recoveries following removal of the lesion.

TABLE 7.—*Spinal Extradural Cysts (3.7 per Cent)*

Case No.	Age, Yr.	Sex	Duration of Cord Compression	Clinical Findings	Roentgenogram of Spine	Pathologic Features	Result
36	51	F	3 mo.	Spastic paraparesis; position and vibration senses lost in legs	Fusiform erosion pedicles T-7 to T-9	Cyst attached to root T-9 (6 by 2.5 by 2.5 cm.); no lining layer	Complete recovery 2½ yr. postoperatively
37	13	F	2 yr.	Spastic paraparesis; position and vibration senses lost in feet; temperature and pain senses questionably altered	Fusiform erosion pedicles T-6 to T-8	Cyst (7 by 2 by 1.5 cm.) not visibly attached to surrounding structures; lining layer of low columnar cells	Complete recovery 1½ yr. postoperatively

TABLE 8.—*Epidural Hemorrhage (5.6 per Cent)*

Case No.	Age	Sex	Duration of Symptoms	Nature of Symptoms	Apparent Etiology	Roentgenogram of Spine	Operative Findings	Result
38	42 yr.	M	1 wk.	Flaccid paraplegia; onset within 2 hr.; no pain	Sudden turn in bed	Normal	Cystic, encapsulated hematoma T-2 to T-5; cord pale	Unimproved 1 yr.
39	20 mo.	M	2 wk.	Flaccid paraplegia; complete in 10 days; no pain ?	Systemic infection ?	Normal	Encapsulated cystic hematoma T-0 to T-7	Completely well 1½ yr.
40	56 yr.	M	18 hr.	Flaccid paraplegia; progressive over period of 6 hr.; mild pain	Trauma; vascular disease	Compressed fracture T-8	Epidural hemorrhage T-7 to T-9	Died 2 yr. postoperatively; unimproved

CHRONIC EPIDURAL HEMORRHAGE

The occurrence of bleeding into the spinal canal with hematoma formation resulting in cord compression is apparently a rare entity [31]

29. Elsberg, C. A.; Dyke, C. G., and Brewer, E. O.: The Symptoms and Diagnosis of Extradural Cysts, Bull Neurol. Inst. New York **3**:395, 1934.

30. (*a*) Lehman, E. B.: Spinal Extradural Cysts, Am. J. Surg. **28**:307, 1935. (*b*) Cloward, R. B.: Spinal Extradural Cysts, Ann. Surg. **105**:401, 1937. (*c*) Cloward, R. B., and Bucy, P. G.: Spinal Extradural Cyst and Kyphosis Dorsalis Juvenalis, Am. J. Roentgenol. **38**:681, 1937. (*d*) Kelly, T. S. B.: Non-Parasitic Extradural Cyst of the Spinal Canal, Lancet **2**:13, 1937. (*e*) Robertson, J. F., and Graham, C. P.: Spinal Extradural Cyst Associated with Kyphosis Dorsalis Juvenalis, Ann. Surg. **110**:285, 1939. (*f*) Turnbull, F.: Spinal Extradural Cyst, Canad. M. A. J. **41**:250, 1939. (*g*) Adelstein, L. J.: Spinal Extradural Cyst Associated with Kyphosis Dorsalis Juvenalis, J. Bone & Joint Surg. **23**:93, 1941. (*h*) Good, C. A.; Adson, A. W., and Abbott, K. H.: Spinal Extradural Cyst, Am. J. Roentgenol. **52**:53, 1944.

31. Wilson (Wilson, S. A. K.: Neurology, Baltimore, Williams & Wilkins Company, 1940, p. 1157) discussed hematorachis at length and cited a case of epidural hematoma following a fall and resulting in the onset of cord compression several weeks after the injury.

(table 8). Although trauma frequently results in hemorrhage into the spinal canal, extradural, subdural or intramedullary, this usually does not present the surgeon with an indication for operation, for the hemorrhage per se rarely results in cord compression.

Two patients, recently encountered, proved at operation to have hematomas in the spinal epidural space, which caused cord compression and which were strikingly similar to the chronic hematomas encountered in the intracranial subdural space. They were greenish, cystic masses consisting of a membrane, easily peeled off the dura, which enclosed brown, coffee-colored fluid. Both were located in the upper thoracic portion of the spine. Microscopically they consisted of a fairly dense connective tissue membrane, the inner portion of which was a relatively loose meshwork containing many dilated thin-walled capillaries filled with blood (fig. 7). Blood pigment was scattered throughout the inner portion of the membrane. The outer portion of the membrane was composed of denser fibrous tissue, and in one a limiting single layer of flattened cells could be distinguished. In neither instance was there a definite history of trauma, nor was there any roentgen ray evidence of old fracture. One patient was a child of 20 months who had had an acute infection with high fever, extreme irritability and erythema from which he apparently recovered. However, some three weeks later, there was a recurrence of irritability, some fever and, in addition, weakness of the lower limbs. The weakness progressed in ten days' time to almost complete flaccid paralysis. There was evidence of a complete block by both the Queckenstedt maneuver and oil myelography. Laminectomy revealed the previously described lesion, and it was completely removed. The child made a good recovery, and rapid neurologic improvement took place. The child was walking and running about normally one year after operation.

Fig. 7 (case 39).—Spinal epidural hematoma. Note the resemblance of the histologic appearance to the more common intracranial subdural hematomas. Hematoxylin and eosin; × 63.

The second patient was a 42 year old man who after a sudden turn in bed noted weakness of his lower limbs. This progressed in two hours' time to complete paralysis. On admission to the hospital one week later, he had a complete flaccid paraplegia and a good sensory level at the fifth or sixth thoracic dermatome. All sphincteric function was lost. He had a complete subarachnoid

block demonstrated by the Queckenstedt maneuver and by oil myelography. Laminectomy was performed, and an epidural hematoma was completely removed. The dura was opened, and the spinal cord underlying the hematoma appeared pale. This man was followed for five months, during which time he had no return of function.

These 2 cases represent a chronic form of epidural hematoma, and in neither instance is the pathogenesis clear. A third patient, with an unequivocal history of trauma resulting in a progressive flaccid paraplegia over a period of eighteen hours, was found to have a recent hemorrhage, localized in the epidural space, producing cord compression. This man, 56 years old, with hypertension (pressure of 200 systolic and 100 diastolic), fell while helping to carry a heavy trunk up a flight of stairs, striking his back against the edge of a step. He had pain in his back at the time of his injury, but the onset of the paraplegia was delayed for four hours after the accident. The weakness progressed slowly from the right to the left leg until there was complete flaccid paraplegia at the time of operation, eighteen hours after injury. Roentgen ray examination of the spine revealed a compressed fracture of the eighth thoracic vertebra, without bony impingement on the intravertebral canal. There was a complete subarachnoid block demonstrated by the Queckenstedt test. Laminectomy, involving the seventh, eighth and ninth thoracic vertebrae, revealed clotted blood filling the epidural space. Postoperative Queckenstedt tests revealed complete relief of the block. Nevertheless, twenty-four months later, there had been no evidence of neurologic improvement, and the patient died of an infection of the urinary tract complicating severe hypertensive and arteriosclerotic renal disease.

ACUTE EPIDURAL SUPPURATION

The entity of acute epidural suppuration is well understood today, and our 6 cases, which form 11.1 per cent of the entire series, emphasize many of the features pointed out by previous reports. The victims of this serious lesion were generally young, 3 in the second decade, 1 in the third and 2 in the fifth decade of life. The course of the illness was short, and the usual picture of epidural lesions — back or root pain followed by cord compression — was present, with, however, a few important variations. The interval between the onset of pain and the appearance of the symptoms of cord involvement was short, generally only one week of pain in the back preceding the onset of paraplegia. In 2 instances, the onset of the pain and of the paraplegia were simultaneous. Another striking variation was the fact that pain was far more severe in this group than in the cases of other types of epidural lesions.

The source of the infection was readily ascertained in each case (table 9), and the interval between the primary infection and the onset of epidural suppuration was no longer than several weeks. On the basis of study of this material, we cannot contribute to the solution of the question of the association of vertebral osteomyelitis with epidural suppuration, save to note that roentgenograms of the vertebral column showed uniformly normal conditions.[32] Inasmuch as the duration of the illness was never longer than two weeks at the time of the patient's admission to the hospital, the lack of positive roentgenographic evidence cannot be considered conclusive. The infectious agent was in all cases a staphylococcus, generally of the hemolytic Staphylococcus aureus variety. This conforms with previously reported cases.[33]

The extent of the epidural suppuration was generally far greater than suspected. In 2 cases in which the lesions appeared clinically to be in the upper thoracic region, pus was recovered from about the lumbar sac on attempted lumbar puncture. In these cases laminectomy was done in both regions and through and through drainage established. In every case free pus was found. In 2 cases there was evidence of beginning encapsulation by granulation tissue.

Two of the patients died in the immediate postoperative period, one of respiratory paralysis immediately after operation, the other of occlusion of a coronary or pulmonary artery nineteen days after operation. The latter patient had shown some evidence of return of function. One patient, who had shown neurologic improvement,

32. Browder, J., and Meyers, R.: Infections of Spinal Epidural Space: An Aspect of Vertebral Osteomyelitis, Am. J. Surg. **39**:4, 1937. Stammers, F. H. R.: Spinal Epidural Suppuration with Special Reference to Osteomyelitis of the Vertebra, Brit. J. Surg. **26**:366, 1938. Browder, J., and Meyers, R.: Pyogenic Infections of Spinal Epidural Space, Surgery **10**:296, 1941.

33. Craig, W. M., and Doyle, J. B.: Metastatic Epidural Abscess of Spinal Cord, Ann. Surg. **95**:58, 1932. Mixter, W. S., and Smithwick, R. H.: Acute Intraspinal Epidural Abscess, New England J. Med. **207**:126, 1932. Gasul, B. M., and Jaffé, R. H.: Acute Epidural Spinal Abscess: A Clinical Entity, Arch. Pediat. **52**:361, 1935. Echols, D. H.: Emergency Laminectomy for Acute Epidural Abscess of the Spinal Canal, Surgery **10**:287, 1941. Campbell, M. M.: Pyogenic Infections Within Vertebral Canal, Bull. Neurol. Inst. New York **6**:574, 1937.

died three months postoperatively of generalized sepsis. Three patients are still alive; 1 is able to get about on crutches, but sphincter function is still absent after six years; another, one and one-half years after operation, has shown pronounced recovery, getting about with a cane, performing his usual sedentary job and enjoying satisfactory control of the bladder. The last

TABLE 9.—*Epidural Infectious Processes: Acute Suppuration (11.1 per Cent)*

Case; Sex; Age, Yr.	Duration of Pain	Duration of Cord Compression	Roentgenogram of Spine	Level of Lesion	Evidences Sources of Infection	Result	Comment
Acute Suppuration (11.1 per cent)							
41 F 12	8 days	18 hr.	Normal	C-3 to L-3	Injured back in automobile accident 10 days previously	Died 1 hr. postoperatively of respiratory paralysis	Hemolytic Staphylococcus aureus cultured
42 M 18	2 wk.	1 wk.	Normal	D-4 to L-4	Infected finger 1 mo. prior; incision and drainage 2 wk. prior	Able to get about on crutches; automatic bladder 6 yr. postoperatively	Hemolytic Staph. aureus cultured
43 M 50	3 wk.	2 days	Normal	T-4 to T-6	Furuncle finger 1½ mo. prior; incised several times	Died 19 days postoperatively of coronary or pulmonary occlusion	Hemolytic Staph. aureus cultured
44 F 49	2 wk.	4 days	Normal	T-8 to T-10	Draining sinus left thigh, 3 yr. duration	Died 3 mo. postoperatively of generalized sepsis	Hemolytic Staph. aureus cultured
45 M 16	2 wk.	2 wk.	Normal	T-2 to T-7	Thrombophlebitis left leg, 7½ yr. of age; pyarthrosis left hip at 10 yr. of age; sinusitis with frontal osteomyelitis at 14 yr.; furuncle on neck 3 wk. prior to epidural abscess	Unimproved 6 mo. postoperatively; not heard from since	Hemolytic Staphylococcus albus cultured
46 M 30	2 wk.	2 wk.	Normal	L-1 to L-5	Appendix removed with patient under spinal analgesia 4 days prior to onset; two furuncles on hand 3 to 4 wk. prior to onset	Coronary occlusion 1½ mo. postoperatively; walking with cane and back at work (office) 1½ yr. postoperatively	Hemolytic Staph. aureus cultured
Chronic Nonspecific Granuloma (5.6 per cent)							
47 F 18	8 mo.	1 mo.	Normal	C-2 to C-4	Pharyngitis and tonsillectomy 4 mo. prior to symptoms	Neurologically normal 10 yr. postoperatively	No culture taken
48 F 55	1 yr.	2 wk.	Normal	T-11 to T-12	None ascertained	Spinal shock postoperatively; died of urinary sepsis and debility 1½ yr. later without functional improvement	No culture taken
49 M 67	2 yr.	2 yr.	Old compressed fracture T-5 vertebra	T-7 to T-8	None ascertained	Unimproved; died 1½ mo. later of generalized sepsis	No culture taken
Syphilitic Granuloma (5.6 per cent)							
50 F 33	6 wk.	3 wk.	Normal	T-3 to T-7	Blood and spinal fluid serologic reactions 4 plus	Neurologically normal 10 yr. postoperatively	Adequate antisyphilitic roentgen ray treatment postoperatively; severe direct trauma to upper thoracic area 2 days before onset of pain
51 M 28	5 mo.	4 mo.	Erosion of vertebra T-5	T-4 to T-7	Blood and spinal fluid serologic reactions 4 plus	Neurologically normal 4 yr. postoperatively	Adequate antisyphilitic roentgen ray treatment postoperatively; indirect trauma to upper thoracic area 1 mo. prior to onset of symptoms
52 M 50	7 mo.	5 days	Roentgenograms unsatisfactory	T-2 to T-5	Reaction to Wassermann test of blood 4 plus; spinal fluid anticomplementary; chancre 20 yr. before	Neurologically normal 2 yr. postoperatively	Adequate antisyphilitic roentgen ray treatment postoperatively; severe direct upper thoracic trauma 8 mo. prior
Tuberculous Granuloma (8.7 per cent)							
53 M 25	5 mo.	2 mo.	Normal	T-4 to T-6	Roentgenogram of chest; bilateral inactive tuberculosis	Improved; able to walk with cane 2 yr. postoperatively	Laminectomy wound never healed; reactivation of chest tuberculosis 7 yr. postoperatively; collapse of vertebral bodies T-6 and T-7 with recurrence of paraplegia; roentgenographic diagnosis: Pott's disease 7 yr. postoperatively
54 M 23	3 mo.	1 mo.	Normal	C-1 to C-6	Cervical adenitis and retropharyngeal mass incised and drained 6 mo. preoperatively; wound did not heal; guinea pig inoculation of mass positive for tuberculosis (reported after laminectomy)	Died 1st postoperative day; respiratory paralysis	Autopsy: epidural granulation tissue communicated with draining sinus of lateral neck; vertebral body C-2 carious

patient was unimproved after six months and has not been heard from since.

EPIDURAL TUBERCULOUS GRANULOMAS

Symptoms of involvement of the spinal cord in cases of vertebral tuberculosis are not uncommon (table 9). This is generally not considered to be a lesion calling for surgical treatment, and, in fact, the results of laminectomy in such cases are extremely poor. However, there are certain instances in which symptoms of cord compression due to epidural tuberculomas occur before any roentgenographic evidence of Pott's disease (tuberculosis of the vertebra) is discernible. In such cases it is virtually impossible to differentiate the lesion from other epidural granulomas or tumors preoperatively.[34] There are 2 such cases in our series. In the first of these, there was little evidence pointing to a specific etiologic agent in the clinical picture, which was of about a half year's duration. A roentgenogram of the spine showed normal conditions, and one of the chest revealed inactive, bilateral apical tuberculosis. Operation disclosed granulation tissue in the epidural space, within which there were small collections of purulent material. The bulk of the granuloma was located anterior to the dura. This biopsy specimen has been lost, but the subsequent history of the patient leaves little room for doubt as to the tuberculous nature of the infection. There was excellent neurologic recovery, but the wound never fully healed, opening and closing alternately at intervals of a few months for seven years following operation. In the eighth postoperative year, there was a recurrence of the paraplegia and roentgenographic study of the spine at that time revealed changes typical of Pott's disease, with collapse of the fifth thoracic vertebra, in the region of previous laminectomy.

The second case of this group was also that of a young man, who had a draining sinus in his neck for a three month period prior to onset of neurologic signs. A persistent draining sinus followed incision of a fluctuant cervical and retropharyngeal mass. There was pain in the back of the neck for two months which was followed by evidence of a Brown-Séquard syndrome at the level of about the third cervical vertebra. The cervical infection was reported not to be tuberculous, since acid-fast bacilli could not be demonstrated in the material obtained at operation. Nevertheless, a chronic infectious process was considered to be the cause of the neurologic change. Roentgen ray examination of the cervical vertebrae was reported as showing nothing abnormal. At operation, the epidural space, particularly anteriorly, was found to be filled with granulation tissue. The patient died of respiratory paralysis on the first postoperative day. Guinea pig innoculation of material from the draining cervical sinus gave positive results for the tubercle bacillus, the report being received after laminectomy had been performed. Autopsy demonstrated that the infected draining sinus of the neck communicated with the anterior epidural space. The specimens removed both at operation and at autopsy proved to be chronically inflamed granulation tissue, with relatively few of the specific histopathologic characteristics of tuberculosis. The postmortem examination also revealed caries of the second cervical vertebral body which had not been disclosed by roentgen ray examination. Although the histologic appearance was not alone conclusive of tuberculosis, the eventual recovery of tubercle bacilli from the draining sinus of the neck by guinea pig inoculation firmly establishes the diagnosis.

SYPHILITIC GRANULOMA

Syphilitic granulomas in the epidural space are apparently unusual entities. In the larger published series of spinal lesions associated with cord compression, there is no mention of epidural gumma (table 9). Elsberg encountered gummatous tissue in the intravertebral canal, but it apparently involved the meninges and was most frequently subdural.[1] Our series includes 3 cases of gumma situated primarily in the epidural space. The dura was generally involved, but the mass of the lesion could be readily removed from it and there was clearly no subdural extension. The granuloma in each instance was a well localized mass of granular, reddish appearance, which encircled the dura as a collar. The relatively large number encountered over a period of only ten years gives unusual interest to the group. The symptoms of these patients were of moderate duration. Pain was generally present for a number of months preceding the onset of cord compression. The cord compression progressed with moderate rapidity over a period of six weeks, five months and seven months in the 3 cases respectively. The Wassermann reaction of both the spinal fluid and the blood of all patients was positive, but there were no clinical findings indicative of other manifestations of syphilis. All lesions were located in the upper thoracic region, and all caused complete subarachnoid block.

34. Butler, R. W.: Paraplegia in Pott's Disease, with Special Reference to Pathology and Etiology, Brit. J. Surg. **22**:738, 1935.

The favorable end results obtained in these cases justify the operative attack. All patients are completely cured ten, four and two years postoperatively. Adequate antisyphilitic therapy was given each patient after operation. We do not know whether the latter alone would have effected as complete a cure, but it appears that relief of the cord compression by operation is the quickest, and therefore the safest, procedure. Laminectomy per se today is associated with such an extremely low mortality that delay seems hardly justifiable.

Microscopically the lesions were fairly typical, there being pronounced fibrosis about areas of necrosis in which structural outlines could still be discerned. In 1 specimen plasma cells were the predominant infiltrating cells, and in this specimen the vascularity was considerably greater than in the other 2 cases. Special stains were made for acid-fast organisms in each instance, but none were found.

It is of interest to note that in each case there is a history of trauma which the patient associated with the onset of symptoms. In 2 of our patients, severe direct trauma was suffered over the site of the lesion two days and one month respectively before the onset of the complaints. In the third, indirect trauma of questionable severity over the site of the lesion was reported as having occurred one month prior to the onset of symptoms. It seems possible that trauma was a precipitating or a localizing factor in the pathogenesis of these gummas.

NONSPECIFIC GRANULOMAS

The clinical picture associated with an epidural, nonspecific granuloma is almost indistinguishable from that of cord tumor. Our series includes the cases of 3 patients with this type of lesion, whose ages were 18, 55 and 67 years, respectively (table 9). Only the youngest patient gave an antecedent history of infection, an infected throat four months earlier for which tonsillectomy had been done. In 2 cases pain in the back was present almost a year before the onset of the symptoms of cord compression. The latter symptoms, however, became pronounced in relatively short periods, two to four weeks. In the third case there was no pain at any time, but the outstanding feature was cord compression progressing over a two year period to complete paraplegia.

At operation, all three lesions were described as fibrous and vascular and firmly adherent to the outer surface of the dura. On microscopic examination a stroma of dense fibrous tissue was seen, infiltrated by many inflammatory cells, among which lymphocytes predominated. Microscopically, one of the lesions showed considerable vascularity, whereas the other two were relatively avascular. This could not be correlated with any differences in the clinical courses. Unfortunately, bacteriologic studies were not made in any of the cases.

The youngest patient (table 9) is alive and has no neurologic residue ten years postoperatively. The remaining 2 patients are both dead. One, who had only a mild paraparesis preoperatively, suffered a severe spinal shock following the attempt to extirpate the lesion completely. She remained paraplegic and died one and one-half years postoperatively of a severe infection of the urinary tract and generalized debility. The third patient had had a complete spastic paraplegia for one year prior to operation, and at operation the spinal cord was observed to be yellow, thinned and anemic at the level of the lesion. He died of infection without showing any neurologic improvement one and one-half months postoperatively.

The literature contains numerous reports of lesions of this type, and our cases conform to those observed and described by others.[35] The failure to demonstrate an etiologic factor appears to be a common experience.

COMMENT AND SUMMARY

The preoperative diagnosis of cord compression in the cases under discussion was readily made, but the nature of the underlying lesion was generally obscure. From this study it appears that each group of epidural lesions is characteristic of a particular period of life.

In the older age group, metastatic carcinoma and myeloma are most common. The clinical history is short, a matter of a few weeks or,

35. Watts, J. A., and Mixter, W. S.: Spinal Epidural Granuloma, New England J. Med. **204**:1335, 1931. Barker, L. F.: Symptoms of Compression of Upper Spinal Cord, Markedly Relieved by Excision of a Mass of Epidural Granulation Tissue, Following upon Chronic Staphylococcic Infection of Adipose Tissue Within the Spinal Canal, Internat. Clin. **1**:1, 1932. Santy, P.; Wertheimer, and Dechaume, J.: Syndrome de compression médullaire aiguë par épidurite localisée, consécutive à un anthrax du cou, Lyon méd. **150**:99, 1932. Turnbull, F. A.; Hyland, H. H., and McKenzie, K. G.: A Staphylococcus Infection Producing an Inflammatory Mass Simulating a Spinal Cord Tumor, Canad. M. A. J. **28**:415, 1933. Léchelle, P.; Petit-Dutaillis, D.; Thévenard, A., and Schmite, P.: Syndrome de compression médullaire en rapport avec une épidurite d'origine rheumatismale probable, Rev. neurol. **1**:222, 1934. Chavany, J. A.; David, M., and Stuhl, L.: Epidurite inflammatoire cryptogenetique, ibid. **67**:499, 1937. Grossman, M. O.; Kesert, B. H., and Voris, H. C.: Chronic Spinal Epidural Granuloma, Ann. Surg. **119**:897, 1944.

at most, a few months, and an eroding vertebral lesion can as a rule be identified by roentgenography. Failure to demonstrate a primary tumor or multiple lesions does not alter the probability that the cord compression is caused by a carcinomatous metastasis or a myeloma. Surgical intervention in these groups has proved futile.

Neuroblastoma and giant cell tumor of bone manifest themselves by cord compression, usually in the early decades of life. Both have short clinical courses, and the former may or may not cause erosion of the vertebral column demonstrable by roentgenogram. Giant cell tumors are primarily lesions of the vertebral column and, once the cord compression is relieved, pursue a benign course. Neuroblastomas are malignant and are usually associated with a posterior mediastinal or retroperitoneal mass.

Tuberculous granuloma associated with a clinical picture simulating that of cord tumor is also a lesion of youth. The clinical course in this group was of moderate duration, four to six months in each case, and in each case tuberculous lesions elsewhere were present preoperatively.

In two other groups of epidural mass lesions affecting young persons there were more specific syndromes. Extradural cysts are associated with a clinical course of long duration with characteristic roentgenologic and neurologic changes. Epidural abscesses are most common in the second to fourth decades and run an explosive course. The general symptoms of infection are present, and usually an antecedent history of a primary suppurative infection can be elicited.

The other varied lesions in our series were encountered in the middle decades of life. The lymphosarcomas, a much rarer lesion in our series than we had anticipated, had short clinical courses, and although generalized lymphadenopathy was absent at the time of operation it appeared shortly thereafter. Patients with these tumors have done well to date, being controlled by intensive irradiation therapy. The preoperative duration of symptoms of gumma was moderately long, lasting from four to twelve months. Wassermann tests of blood and spinal fluid elicited positive reactions in all patients, and all are cured many years after operation.

A majority of the masses occurring in the epidural space in our cases arose primarily in this space. However, a large group unquestionably are extensions from primary lesions of the vertebrae. Myelomas and giant cell tumors certainly fall into the latter category. Metastatic carcinoma in the epidural space is usually associated with bony involvement, but whether metastasis occurred first in the spinal column, in the epidural space, with subsequent extension to the other site, or simultaneously in both cannot be definitely stated.

RESECTION OF THE LUNG IN THE TREATMENT OF PULMONARY TUBERCULOSIS

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Tuberculosis is a systemic infectious disease caused by a specific micro-organism. It most often involves the lung and is usually bilateral, but, fortunately, the major disease area is predominantly unilateral and often unilobar. Prevention of infection or establishment of acquired resistance [1] would be the ideal treatment. Progress is being made in both of these methods.

Since prophylactic treatment is not entirely effective, early recognition of the disease is important. Great advances are being made in this direction by means of roentgenographic examinations of large groups of people.[2] Perhaps in the not too distant future every patient admitted to a hospital will have a roentgenogram made of the chest, just as he now has a urinalysis and a serologic test for syphilis.

Chemotherapy would be the ideal method of treatment of the disease. Various chemical agents are being studied diligently for the arrest of pulmonary tuberculosis, but as yet an effective drug has not been found.[3]

The application of adequate medical measures supplemented by simple surgical procedures will arrest or cure early pulmonary tuberculosis in most cases. For valid reasons the disease will progress to a late stage in certain patients, and these must also be accepted for treatment.

Often in the later stages of the disease, irreversible structural changes occur in the bronchial system, thus causing the failure of simple therapeutic measures. It seems likely that effective chemotherapy, even though it could render the patient bacteriologically free of tubercle bacilli, would not relieve him of all symptoms.

Accurate diagnosis is extremely important in recognizing irreversible structural changes in the lungs and the bronchial system. The use of tomography, bronchography, determinations of intracavitary pressure, bronchoscopy, bronchospirometry and diagnostic pneumothorax as indicated will lead to the correct diagnosis of pulmonary lesions. Only with an accurate diagnosis can the outcome of surgical treatment be predicted. The finding of tubercle bacilli in the sputum has long been insufficient for diagnosis. The unexpected good result or the discouraging poor result from a surgical procedure usually is contingent on an incomplete diagnosis or a misunderstanding of the nature of the disease. Few phthisiologists would recommend thoracoplasty or pneumothorax in the presence of a known stenosis of a main bronchus. It is becoming more evident that the poor end results of thoracoplasty and pneumothorax often are caused by endobronchial disease.[4] Intracavitary drainage is indicated for a cavity with positive pressure but definitely contraindicated if there is an atmospheric or a negative pressure within the cavity.[5] In the present state of knowledge, thoracoplasty is contraindicated when a cavity is in a phase of increased pressure and should certainly not be recommended when pulmonary tuberculosis is complicated by bronchiectasis. Thoracoplasty is never justified as a trial method of treatment; however, a trial with pneumothorax often is permissible.

If the contralateral lung is free of disease, pulmonary resection appears to be the best treatment after the occurrence of irreparable damage, such as bronchial stenosis, bronchial disease with or without ulcerations not responding to bronchoscopic treatment, bronchiectasis and unsuccessful thoracoplasty. When such a condition exists, it is either because treatment failed in the early stages of the disease or because it was not started. The

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1. Rich, A. R.: The Pathogenesis of Tuberculosis, Springfield, Ill., Charles C Thomas, Publisher, 1944, p. 477.

2. Ashbury, H. E.; Whildin, J. G., and Rogers, F. T.: Roentgenological Report of Chest Examinations, Am. J. Roentgenol. **48**:347, 1942. Goorwitch, J.: Mass Chest Roentgenography and Admissions to Olive View Sanatorium, Am. Rev. Tuberc. **50**:214, 1944.

3. Pfuetze, K. H.: Present Status of Chemotherapy in Tuberculosis from Clinical Standpoint, Dis. of Chest **11**:220, 1945.

4. Brantigan, O. C.; Hoffman, R., and Proctor, D. F.: Endobronchial Tuberculosis, Am. Rev. Tuberc. **45**:477, 1942.

5. Vineberg, A. M., and Kunstler, W. E.: The Determination and Treatment of Pressure Cavities in Pulmonary Tuberculosis, Surg., Gynec. & Obst. **78**:245, 1944.

mortality rate of pulmonary resection has been reduced to a reasonable level in the past few years by the improvement in operative and anesthetic technic. This reduction is extraordinary when the report of Thornton and Adams [6] is compared with the recent literature.[7]

The distant future perhaps holds more danger for the tuberculous patient who has had a pulmonary resection than does the operative or immediate postoperative period. Activation of dormant disease, reinfection or new infection of the healthy residual pulmonary tissue may occur. However, these dangers must be weighed against the possible ill effects of a major focus of disease remaining as a threat to the patient for years. A breakdown of the bronchial stump, with fistula formation possibly associated with empyema, may occur months after the operation. In view of the present developments, the prognosis cannot be foretold for the patient undergoing a pulmonary resection for tuberculosis. Nevertheless, the phthisiologist fully realizes what the future holds for the tuberculous patient with uncontrollable bronchial disease, bronchial stenosis, bronchiectasis and unsuccessful thoracoplasty.

Pulmonary resection is the only form of treatment that can be used effectively when pneumothorax or phrenic paralysis, with or without pneumoperitoneum, does not control basilar disease, a cavity against the mediastinal surface in the lower half of the chest or a cavity in the middle portion of a lung. The isolated tuberculoma represents a localized form of pulmonary tuberculosis which rarely occurs. It is perhaps the only condition in which all of the disease tissue can be excised. The tuberculoma often is incorrectly diagnosed as a neoplasm.

Controversy is invited when lobectomy is suggested for the treatment of a tension cavity [7e] and for unilateral or unilobar disease in a young person. Before the procedure can justly be denied or affirmed, further study and experience are needed. Real contention and perhaps just criticism are encountered when a lobectomy of the upper lobe is elected as a method of choice instead of a thoracoplasty. It is only natural that a more efficient, easier and quicker form of treatment should be sought, even in the face of what appears to be an acceptable adequate method of treatment. However, the criticism of elective lobectomy of the upper lobe for tuberculosis must not be allowed to react generally against pulmonary resection for tuberculosis. Based on the present state of knowledge, Chamberlain [8] has offered convincing arguments against elective lobectomy of an upper lobe. Nevertheless, good results in the whole field of medical and surgical practice depend primarily on treatment instituted early in the course of any disease.

REPORT OF CASES

CASE 1.—Mrs. M. R., a white woman aged 30, in whom the onset of the disease was noted in 1935, at one time had bilateral pneumothorax induced. This procedure was discontinued because the disease was not controlled. In 1941 a one stage thoracoplasty was done on the right side, and it was followed by empyema. A bronchoscopic examination revealed endobronchial disease in the right bronchus, with gradual narrowing of the right main bronchus. In 1943 a two stage thoracoplasty was done, with a partial revision of the original operation. The patient continued to have considerable cough, and the sputum contained Mycobacterium tuberculosis. The right main bronchus narrowed to a few millimeters. A bronchospirometric determination revealed practically no function on the right side.

An operation was performed on May 1, 1944, through an anterior incision. The hilar structures were exposed adequately, and the pulmonary artery and veins were ligated and divided. The bronchus was extremely small and was surrounded by considerable fibrosis. The bronchus was clamped and divided. Up to this point the operation was tedious but not difficult. In the endeavor to free the lung from the chest wall, almost insurmountable difficulty was encountered because of the fixation of the lung to the chest wall. When the lung finally was removed there was profound shock, out of proportion to the loss of blood. The patient died while the chest wall was being closed.

Comment.—If the unsuccessful thoracoplasty could have been predicted after the failure of pneumothorax on the right side, a pneumonectomy should have been performed as a primary type of treatment. With the present advanced knowledge of the disease, it seems obvious that a patient with this bronchial condition should not be subjected to a thoracoplasty. The patient was the only one in this small series who died.

6. Thornton, T. F., Jr., and Adams, W. E.: The Resection of Lung Tissue for Pulmonary Tuberculosis, Internat. Abstr. Surg. **75**:312, 1942; in Surg., Gynec. & Obst., October 1942.

7. (*a*) Churchill, E. D., and Klopstock, R.: Lobectomy for Pulmonary Tuberculosis, Ann. Surg. **117**:641, 1943. (*b*) James, R. M.: Total and Partial Pneumonectomy in Treatment of Pulmonary Tuberculosis, J. Thoracic Surg. **14**:3, 1945. (*c*) Maier, H. C.: Surgical Treatment of Tension Cavities in Pulmonary Tuberculosis, Am. Rev. Tuberc. **51**:1, 1945. (*d*) Maier, H. C., and Klopstock, R.: Lobectomy for Pulmonary Tuberculosis, J. Thoracic Surg. **14**:20, 1945. (*e*) Overholt, R. H., and Wilson, N. J.: Pulmonary Resection in the Treatment of Pulmonary Tuberculosis, Am. Rev. Tuberc. **51**:18, 1945; (*f*) Pulmonary Resection for Tuberculosis Complicated by Tuberculous Bronchitis, Dis. of Chest **11**:72, 1945; (*g*) Pulmonary Resection in the Treatment of Tuberculosis, J. Thoracic Surg. **14**: 55, 1945.

8. Chamberlain, J. M.: Primary Upper Lobectomy Versus Modern Selective Thoracoplasty in Treatment of Tuberculosis, J. Thoracic Surg. **14**:32, 1945.

CASE 2.—Mrs. K. M., a white woman aged 43, first contracted pulmonary tuberculosis about 1930. She received medical care from time to time and for the most part was reluctant to continue any specific routine of treatment.

In December 1942 sudden atelectasis of most of the left lung occurred. A bronchoscopic examination revealed tuberculous involvement of the trachea and left bronchus. Response to treatment was excellent, but narrowing of the left main bronchus was evident. The atelectasis continued without change, and the sputum remained positive for Mycobacterium tuberculosis.

On Aug. 31, 1944 a pneumonectomy of the left lung was done without difficulty. The patient had an uneventful postoperative course and was discharged from the hospital twenty-seven days after operation.

Three days after she returned home, thrombophlebitis developed in the left leg and followed a mild course. The patient could not be induced to produce sputum for examination; gastric washings were not obtainable. and a roentgenographic examination of the chest was refused after she returned home. A clinical examination revealed no abnormal conditions other than minor difficulty with the left leg. The patient was in good health when she moved to another part of the country, in April 1945.

Comment.—As far as can be determined by insufficient study, this patient is well at the present time. She may still encounter trouble from tuberculosis, but that seems less probable than if a hopelessly diseased left lung were still present. Since pneumonectomy was the first type of surgical treatment, the operation was technically simple as compared with that in case 1. It is important to point out that this patient maintained an uninvolved right lung for about fourteen years.

CASE 3.—Mrs. M. L. was a 29 year old white woman whose illness began with hemoptysis in June 1942. A disease of the base of the right lung was diagnosed. In January 1943 cervical adenitis was noted, and the patient was given roentgen ray therapy. On Feb. 11, 1943 a temporary paralysis of the phrenic nerve was produced on the right side. A pneumothorax was initiated on the right side on the following August 26. No adhesions were observed. The lower lobe of the right lung became atelectatic. A bronchoscopic examination revealed endobronchial disease in the bronchus of the lower lobe of the right lung. This lesion did not respond to bronchoscopic treatment, and there developed a progressive fibrotic stenosis with an ulcer of the bronchus of the same lobe. A lobectomy was decided on, and two days before the scheduled operation the patient had a severe hemoptysis. Nevertheless, the operation was carried out as planned.

On April 3, 1944 a lobectomy of the lower and middle lobes of the right lung was done. Considerable difficulty was encountered because there was no fissure between the upper and middle lobes. The known bleeding ulcer was opposite the orifice of the bronchus to the middle lobe; accordingly, it was necessary that the middle lobe be resected. Technically, a pneumonectomy would have been less difficult, but the upper and middle lobes were free of palpable disease and it was desired to conserve pulmonary tissue. At the completion of the operation, air was leaking from the injured remaining upper lobe.

The patient went into shock on being returned to her room, but this was overcome by adequate therapy. The right pleural cavity was connected to negative pressure suction of approximately 1 cm. of mercury. Air leaked from the left pleural cavity for about two weeks, and then the leakage ceased. The drainage tube was removed, and the opening healed promptly. On the first postoperative day the patient's temperature was 104 F. rectally and reached a peak of 105.2 F. on the thirteenth postoperative day. The pulse rate was commensurate with the temperature, reaching a maximum of 140. The respiratory rate was never above 28 per minute. The patient was not in distress but showed signs of failing on the thirteenth postoperative day. Her temperature gradually returned to normal, and it did not go above 99 F. orally after the thirty-ninth postoperative day. Neither empyema nor wound infection occurred, and she was discharged from the hospital on the forty-ninth postoperative day. Despite every effort, the cause of the fever was not definitely determined.

The sputum was negative for tubercle bacilli immediately after the operation and remained so for about six months, at which time it became positive. A bronchoscopic examination revealed tuberculous granulation tissue in the bronchial stump, which seemed to respond to the application of silver nitrate.

Comment.—This case presents the interesting problem of accurate diagnosis and endobronchial disease uncontrolled by adequate bronchoscopic treatment. Since the bronchial ulcer was opposite the orifice of the bronchus to the middle lobe, the middle lobe had to be removed, even though it was free of disease. There was also the technical difficulty of a nonfissured lobe whose removal resulted in a leakage of air from the injured upper lobe. It is important to point out that empyema did not develop. In spite of the leaking of air from the injured upper lobe, the pleural space was obliterated by negative pressure suction. Perhaps pneumonectomy would have been safer. Thus the question arises as to whether a normal lobe should be sacrificed. Churchill has stated his emphatic belief that technical difficulties should not be overcome by sacrificing a healthy lobe.[7a]

CASE 4.—Mrs. E. B., a white woman aged 28, complained of a cough all her life. In February 1939 pleurisy with effusion developed in the right lung. In August 1941 her sputum was positive for tubercle bacilli for the first time. The patient continued to have the cough, expectoration and positive sputum. A roentgenogram revealed involvement of the lower lobe of the right lung. Bronchoscopic examination revealed pus oozing from the lower lobe of the right lung, and the results of the examination were highly characteristic of bronchiectasis. A bronchogram showed bronchiectasis which was confined to the lower lobe of the right lung. The middle lobe of the right lung was normal.

At operation, on April 14, 1944, the lower lobe of the right lung was removed without difficulty. The postoperative course was uneventful.

The sputum proved negative for tubercle bacilli after operation. In October it became positive. There was no roentgenographic evidence of tuberculous parenchymal involvement of the remaining pulmonary fields. Bronchoscopic examination revealed tuberculous granulation tissue in the bronchial stump, which now appears to be responding to the application of silver nitrate.

Comment.—The patient clinically is in good health, but her general condition was satisfactory before operation. If the bronchial stump can be healed, the end result should be satisfactory.

CASE 5.—L. E. was a white youth aged 18, whose condition was first diagnosed as pulmonary tuberculosis at the age of 15. Under adequate medical care, his sputum became negative for tubercle bacilli, but he continued to have symptoms of bronchiectasis. A bronchogram revealed the bronchiectasis to be limited to the lower lobe of the left lung and the lingula of the upper lobe of the left lung.

On Sept. 7, 1942 a lobectomy of the lower lobe of the left lung and a resection of the lingula of the upper lobe of the same lung were done. The pathologic study revealed the expected tuberculosis and bronchiectasis. He had an uneventful postoperative course.

His sputum has remained negative since operation, and he is free of all symptoms.

Comment.—This patient's sputum was negative before operation, but it formerly had been positive. It seems evident from the pathologic study that it would again have become positive in the future. Even though the sputum was negative, there were symptoms of bronchiectasis from which he needed relief.

CASE 6.—D. R., a white woman, first noted the onset of her disease in November 1942. She was admitted to the sanatorium on April 13, 1943, and the initial roentgenogram revealed extensive infiltration throughout both lungs, with most definite changes in the base of the right lung. A bronchoscopic examination on May 18, 1943 showed an accessory bronchus arising from the trachea 4 cm. above the bifurcation of the trachea. This accessory orifice was filled with granulation tissue. Through a bronchoscopic examination on October 5, it was found that the granulation tissue previously noted had disappeared. The patient improved greatly, and there was no roentgenographic evidence of disease, with the exception of a cavity at the base of the right lung. A bronchogram revealed minor bronchiectasis in the lower lobe of the right lung.

On Jan. 27, 1944 a lobectomy was done, the lower and middle lobes of the right lung being removed. The lower lobe was adherent everywhere. The patient was never in a critical condition after the operation, but her temperature rose to 105 F. on the third postoperative day and gradually subsided to 99 F. in thirty days. A roentgenogram made the day after the operation revealed infiltration in the midlung region of the contralateral lung, which undoubtedly indicated an activation of the disease that had been apparent in this area about one year before.

The sputum has been consistently positive since operation. The roentgenogram showed gradual clearing of the contralateral disease. A bronchoscopic examination on June 5, 1945 revealed granulation tissue in the bronchial stump of the lower lobe of the right lung. There was also an ulcer at the orifice of the bronchus to the upper lobe of the left lung.

Comment.—This patient was in good general condition before operation and had a positive sputum. She has been unchanged by the operation, but a cavity of the lower lobe has been removed and there are no cavities at present. This is a case in which perhaps too recently active tuberculous disease had been present in the contralateral lung, and the lesion did not heal completely before operation. The condition should be compared with that in case 2, in which the contralateral lung was kept free of disease for fourteen years. This is the only patient who has had a known activation or occurrence of the disease in remaining lung tissue.

CASE 7.—F. C., a Negro man aged 22, had pleurisy in December 1943. He was later rejected by the Army because of pulmonary tuberculosis. Although he disclaimed all symptoms, he was admitted to the sanatorium on Aug. 31, 1944 but left, contrary to medical advice, six weeks later. On November 7 he was readmitted. A roentgenogram showed a cavity at the base of the right lung, with infiltration of the middle lobe of the right lung. Bronchoscopic examination revealed purulent matter oozing from the bronchus of the lower lobe of the right lung but no other abnormalities.

On November 24 a lobectomy of the lower and middle lobes of the right lung was done. There were many small palpable nodules in the upper lobe of this lung. The patient's postoperative course was uneventful, and he left the sanatorium on Jan. 20, 1945, again disregarding medical advice.

After operation several examinations of sputum did not reveal tubercle bacilli, but before leaving the sanatorium he had one specimen which was positive. He was examined by the city health department on May 9. His sputum was negative for tubercle bacilli, and his condition seemed excellent.

Comment.—This patient was relieved of a diseased lobe of the lung that could not reasonably have been expected to heal. His clinical course is excellent. The operation has been too recent for any optimism with regard to complete recovery, and this is especially true when the patient's race is considered.

CASE 8.—C. R. is a white man aged 26 years, whose illness began in 1936. He had repeated attacks of fever, the cause of which was undiagnosed. After 1942 he had less clinical trouble, but an abnormal roentgenographic shadow persisted that would spread and regress. His sputum apparently was not examined early in the disease; however, it was negative for tubercle bacilli before operation. The conditions observed on bronchoscopic and bronchographic examination were normal. He was subjected to operation, with a tentative diagnosis of tuberculosis, pulmonary abscess or, most unlikely, a neoplasm.

On Feb. 23, 1943 a lobectomy of the middle lobe of the right lung was performed. A well encapsulated mass measuring 2 cm. in diameter was found, but there was no reaction in the tissue about the mass. The diagnosis from the microscopic examination was tuberculoma with caseous necrosis and calcification. The postoperative course was uneventful. His clinical condition has remained excellent, and the sputum continues to be negative for tubercle bacilli.

Comment.—This patient's sputum did not contain tubercle bacilli preoperatively, nor has it since operation. The tuberculoma is the ideal

type of tuberculous pulmonary disease for treatment by lobectomy.

CASE 9.—V. G. was a white woman aged 29 years, whose present condition started with pleurisy in 1936. An acute illness in 1938 was diagnosed as tuberculosis. On Oct. 26, 1942 a temporary paralysis of the phrenic nerve was produced for a small apical cavity. The patient was kept at rest in bed, and a roentgenogram showed that the cavity had disappeared entirely; the sputum also gave a negative reaction. Contrary to medical advice, she became pregnant and delivered a normal baby. This was followed by a second temporary paralysis of the phrenic nerve on Nov. 22, 1944. In spite of treatment, there was extension of the apical disease and an opening of the apical cavity. The sputum was positive for tubercle bacilli. Pneumothorax could not be initiated. A thoracoplasty was advised but refused. The parents of the patient also opposed a thoracoplasty but elected lobectomy, and this decision was acceptable to the physicians.

On May 4, 1945 a lobectomy of the upper lobe of the right lung was performed. The pleural space was obliterated completely by adhesion of the parietal and visceral pleurae. The lung was easily freed from the parietal pleura, except over the cavity, and that area was freed from the chest wall by extrapleural stripping. The pleural cavity was closed without drainage. The patient's postoperative course was entirely uneventful.

Comment.—This is the only elective lobectomy and the only lobectomy of an upper lobe in this series. The patient was an excellent candidate for thoracoplasty. As usual, the sputum was negative for tubercle bacilli immediately after the operation. It is the only instance of a lobectomy that was closed without drainage. Aspiration of the chest was not necessary. Time alone will determine the future course of tuberculosis in this patient.

COMMENT

Dissection of the hilar structures, permitting individual ligation of the pulmonary artery and veins and allowing adequate suture of the bronchus with silk, has greatly reduced the development of bronchial fistulas. None has occurred in this small series. In the earlier cases the bronchial division was made immediately distal to the point of division of the secondary bronchi from the major bronchus to the lobe.[9] This technic caused a long bronchial stump, but bronchial closure was made at a narrow point. The occurrence of tuberculosis of the bronchial stump led to a change of technic for the last patient, for whom division of the bronchus was made at the point at which the bronchus to the lobe branched from the main bronchus; thus, a short bronchial stump was obtained.

The hilar dissection in persons with tuberculosis has been uniformly easier than in persons with other pulmonary conditions requiring a lobectomy or pneumonectomy. Interlobar fissures usually are incomplete; therefore pneumonectomy is a cleaner operation because pulmonary tissue invariably must be cut through in a lobectomy. There is almost invariably an incomplete fissure between the upper and lower lobes posteriorly. This incomplete interlobar fissure is a particularly well known anatomic fact. Unfortunately, tuberculous disease often is located in the upper portion of the lower lobe, which places it at the region of the incomplete fissure. Every effort is made to avoid cutting into tuberculous tissue; thus, resection frequently must be carried into the remaining healthy lobe. Technically, it is often less difficult to do a pneumonectomy.

No drainage is used in cases of pneumonectomy and lobectomy of the upper lobe, since there is no method of immediately obliterating the pleural space. Two grams of sulfanilamide and 150 to 200 cc. of chloroazodin (1:3,300) in sodium tetradecyl sulfate (1:500) are placed in the pleural cavity. There is experimental evidence[10] that this combination of drugs has great bactericidal effect, and the clinical application has been satisfactory.[11] The same drug and solution are placed in the pleural cavity when a lobectomy of the lower lobe is done, even though it is drained. If the remaining lobes are freed completely from the parietal pleura, the pleural space can be obliterated quickly by using a low negative pressure suction apparatus.[9] Obliteration of the pleural space usually will prevent both pyogenic and tuberculous infections. It also offers some assurance against opening of the bronchial stump. All lobectomies of the lower lobes in this series were drained by negative suction. Since penicillin now is available, it is used by intramuscular injection before and after operation.

From an empiric study of many cases of thoracoplasty it appears that the preoperative and postoperative administration of a sulfon-

9. Brantigan, O. C., and Looper, E. A.: The Etiology and Surgical Treatment of Lung Abscess, South. M. J. **37**:199, 1944.

10. Neter, E.: An in Vitro Study on the Synergistic Action of Sulfamido Compounds and Azochloramid upon Various Pathogenic Microorganisms, J. Pharmacol. & Exper. Therap. **74**:52, 1942. Petroff, S. A., and Schain, P.: The Enhancement of Bactericidal Properties of Well Known Antiseptics by Addition of Detergents, Quart. Bull., Sea View Hosp. **5**:372, 1940. Schmelkes, F. C., and Wyss, O.: Inactivation of Sulfonamide Inhibitor by Azochloramid, Proc. Soc. Exper. Biol. & Med. **49**:263, 1942.

11. Brantigan, O. C., and Owings, J. C.: Sodium Tetradecyl Sulfate Used in the Treatment of Acute Pyogenic Empyema of the Pleural Cavity, Bull. School Med. Univ. Maryland **26**:247, 1942. Brantigan and Looper.[9]

amide drug will protect the patient from operative or postoperative pneumonia and perhaps from a spread of the tuberculous disease. Penicillin probably will be equally effective. However, sulfonamide drugs will not prevent a flare-up of a preexisting lesion that has not been healed completely, and the flare-up in case 6 is a good example. A patient with a recently healed contralateral disease does not have a favorable prognosis when faced with operation, in spite of a statement by Overholt to the contrary.[7f] This is the experience gained from performing thoracoplasties and is equally applicable to pulmonary resections.

Intratracheal ether [12] or gas, oxygen and ether anesthesia was used in all cases by doctors trained in anesthesia who endeavored to prevent aspiration of secretions into the other parts of the lung. After operation the patients are given carbon dioxide inhalations and encouraged to cough and move frequently in order to forestall pulmonary complications. The patients receive 500 cc. of whole citrated blood twenty-four hours before operation and 500 to 1,000 cc. of blood during the operation. The patient is placed in an oxygen tent for at least twenty-four hours postoperatively.

In 5 of the 9 cases reported here the patients had endobronchial disease. In patients with previous endobronchial disease it seems reasonable to expect that tuberculous infection of the bronchial stump will occur more often than it will in persons without previous demonstrable bronchial disease. Because of position, it will occur more frequently in the bronchial stump of the lower lobe than in that of the upper lobe. Secretions cannot be retained easily in a bronchial stump of an upper lobe. When tuberculous disease of the bronchial stump occurs, there is always the danger of formation of fistulas months or years after the operation. Endobronchial disease often responds to the bronchoscopic application of silver nitrate even when an infected lung is distal. It is likely that treatment of infection of the bronchial stump will be more efficient. If after pulmonary resection the patient has a positive sputum and no demonstrable pulmonary disease, the bronchial stump should be suspected as the source of the bacilli. In order to avoid and to diagnose tuberculous infection of the bronchial stump, Overholt [7g] has recommended routine bronchoscopic examination of the patient six weeks and again six months after operation.

The necessity or desirability of thoracoplasty following pulmonary resection must be considered seriously. Thoracoplasty would obviate overdistention of the remaining lung and its associated ill effects; however, it would greatly increase the magnitude of the operative work and from that viewpoint is undesirable. Thoracoplasty becomes a necessity when complications such as empyema or fistulas occur. This procedure should not be planned deliberately as a trial treatment preliminary to pulmonary resection. Thoracoplasty after pulmonary resection was not performed for any patient reported on here.

The late end results are fragmentary, as they are in all writings on this subject. The results in this series will be found with the case histories. The conclusion reached by Thornton [6] is evidently true: The best results after operation can be expected from the patient with sputum negative for tubercle bacilli or intermittently negative before operation. In 8 of the patients described, as long as the end result is better than the preoperative condition, there has resulted a definite benefit to the patient, even though a complete cure has not been obtained. The ideal is reached when a cure is effected. The patient should have a prolonged rigid routine of medical care following pulmonary resection, since it is unlikely that all tuberculous pulmonary tissue will have been removed. These patients were in good clinical condition before operation, and, except for 1 death, all are in good clinical condition at the present time.

The only honest objection to pulmonary resection for tuberculosis exists in the elective lobectomy of the upper lobe instead of thoracoplasty, as in case 9. Such criticism should not be allowed to confuse the whole field of pulmonary resection for tuberculosis. There has not been a great number of such cases reported, but the results have been uniformly good. This type of disease can be treated adequately by thoracoplasty. With thoracoplasty the operative work is safer, there is much less danger of immediate postoperative complications and the long range future prognosis is known to be excellent. After thoracoplasty there is less disturbance to pulmonary function, as ably pointed out by Chamberlain.[8] Since tuberculosis usually is multilobar, it seems improbable that all the diseased tissue can be removed by lobectomy.[13] Overdistention of the

12. Murphy, J. D.: Ether Anesthesia in Pulmonary Tuberculosis, Am. Rev. Tuberc. **49**:251, 1944. Beecher, H. K., and Adams, R.: Ether Anesthesia in the Presence of Pulmonary Tuberculosis, J. A. M. A. **118**:1204 (April 4) 1942.

13. Kinsella, T. J.: Lobectomy, Lobostomy, and Pneumonectomy in the Tuberculous, Surg., Gynec. & Obst. **76**:508, 1943.

remaining pulmonary tissue might encourage activation of a lesion in a remaining diseased lobe, whereas with thoracoplasty it is well known that collapse of the apical region brings about relaxation throughout the whole chest and favors continued healing of any remaining diseased area. On the other hand, it should be clearly recognized that the best results from lobectomy in tuberculosis are likely to come from treatment of early or minimal lesions. The thought is not new, because Tuffier undoubtedly had this in mind when he performed a successful pulmonary resection for tuberculosis in 1891.[14] It is important to consider the end results of elective lobectomy of the upper lobe in a separate category.

14. Jones, J. C., and Dolley, F. S.: Lobectomy and Pneumonectomy in Pulmonary Tuberculosis, J. Thoracic Surg. 8:351, 1939.

CONCLUSIONS

1. Pulmonary resection for tuberculosis is a relatively safe operation.

2. The late end results are as yet unknown.

3. In cases in which the disease has brought about irreversible structural changes in the lung and bronchial system, pulmonary resection is definitely indicated. As long as the postoperative condition is an improvement over the preoperative one, the patient has been definitely benefited, even though the disease is not cured.

4. The status of elective lobectomy of the upper lobe for tuberculosis instead of thoracoplasty is yet to be determined.

STUDIES ON MUSCLE ATROPHY

A METHOD OF RECORDING POWER IN SITU AND OBSERVATIONS ON EFFECT OF POSITION OF IMMOBILIZATION ON ATROPHY OF DISUSE AND DENERVATION

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This work was undertaken in an attempt to determine two points: (1) the optimum position of fixation of limbs in order to conserve muscle power and (2) the best method of treatment of muscles paralyzed by loss of nerve supply.

In order to accomplish this, it is necessary to determine the power of given muscles in living animals, then to immobilize these muscles in various positions over an arbitrary period and finally to remove the immobilization and determine the power in the muscles at intervals in order to learn the effect of the immobilization and the ability of the muscle to return to normal with use. This having been accomplished, a series of muscles should be denervated, treated in the same manner and subjected to various types of physical therapy.

As it is stated, the problem seems relatively simple, and we entered on the project with confidence. This we did in spite of the fact that one of us (J. A. K.) has been interested in the problem for over twenty years and in the past has made a few desultory and eminently unsuccessful attempts to solve it. We have not completed the work to our satisfaction, and it is probable that we shall not have an opportunity to extend our investigations further, certainly not in the immediate future.

It is important that this work be carried to its ultimate conclusion because this will place much of the treatment of injured extremities on a sound experimental basis instead of on the basis of accumulated clinical impressions. The method of determining muscle power which we have devised may be useful to others or may serve as a point of departure for improved methods.

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A review of the literature on muscle physiology shows that many of the studies on disuse and denervation atrophy have been done by noting loss of weight and biochemical changes in the affected muscle groups. Results from the experiments using loss of weight as a criterion of atrophy have not been consistent. The normal difference in weight between the two gastrocnemius-soleus groups of muscles in rabbits has been reported as 3.6 per cent by Langley[1] (1916), 4.5 per cent by Thompson[2] (1934) and as high as 6 to 7 per cent by Lipschütz and Audova[3] (1921). Roberts[4] (1916) stated that the amount of wasting is so variable in rabbits that any experiments in which loss of weight is adopted as a measure of degeneration are of little value. Legg[5] (1908) studied atrophy by sectioning the muscles involved and measuring three hundred muscle fibers in cross section.

Various workers have performed functional studies on muscles, but in these studies, again, clinical conditions have been greatly compromised. Some have dissected the muscles completely free before stimulating them. Others have left the blood and nerve supply to the muscle intact but have dissected the achilles tendon free, so that the animal had to be killed after one stimulation. Hartman and Blatz[6] (1919), using rabbits, and Hines, Thomson and Lazere[7] (1942), using rats, employed the latter

1. Langley, J. N.: Observation on Denervated Muscle, J. Physiol. **50**:335-344, 1916.

2. Thompson, T. C.: Experimental Muscular Atrophy, J. Bone & Joint Surg. **16**:564-571, 1934.

3. Lipschütz, A., and Audova, A.: The Comparative Atrophy of Skeletal Muscle After Cutting the Nerve and After Cutting the Tendon, J. Physiol. **55**:300-304, 1931.

4. Roberts, F.: Degeneration of Muscles Following Nerve Injury, Brain **39**:297-347, 1916.

5. Legg, A. T.: Cause of Atrophy in Joint Disease, Am. J. Orthop. Surg. **6**:84-90, 1908.

6. Hartman, F. A.; Blatz, W. E., and Kilborn, L. G.: Studies in the Regeneration of Denervated Mammalian Muscle: II. Effect of Massage, J. Physiol. **53**:108-116, 1919.

7. Hines, H. M.; Thomson, J. D., and Lazere, B.: Quantitative Studies on Muscle and Nerve Regeneration in the Rat, Am. J. Physiol. **137**:527-532, 1942.

method. Martin, Field and Hall[8] (1932) described a method for obtaining isometric contraction of muscles in situ, but the animal was killed with the experiment. Eccles[9] (1941), in a carefully controlled set of experiments on cats, recorded muscle contraction by means of an isometric mirror myograph, but in his experiments, again, it was necessary to kill the animal after one stimulation. The only studies of muscle function in the same animal over a period of time were made by Hartman and Blatz[10] (1920). Etherized rabbits, which were strapped to a board, had sandals tied to their feet in such a manner that contraction of the gastrocnemius group of muscles caused them to lift a weight. Stimulation was supplied through a salt pad over the sciatic region and a brass electrode applied to the muscle group.

In our problem the datum most significant clinically was the power of the muscles. Changes in power of a muscle can be followed only by use of the same animal, and from the review it was apparent that no satisfactory method had been developed for stimulating and recording muscle function repeatedly in the same animal. For this reason we attempted to design a method for study of muscle power which could be used repeatedly and which, in order that the data obtained would have the greatest clinical significance, best simulated clinical conditions with the least sacrifice of physiologic accuracy.

We were immediately faced with the question, "What is the measure of the power of a muscle? Is it the ultimate force that the muscle can exert when subjected to progressively stronger repeated or sustained galvanic or faradic stimulation?" Such experiments damage the muscle, and the results are variable. Likewise, experiments on fatigue and on the ability of a muscle to lift a given weight a variable height were unsatisfactory. It was noted that when the strength of the faradic current is increased gradually a point is reached at which the twitch of the muscle caused by the completion of the circuit equals that caused by the break of the circuit. This break value forms a plateau which extends over a range of several amperes and is relatively constant for the same normal muscle when the experiment is repeated at weekly intervals. We have used the power exerted by a single twitch of the muscle when stimulated at the plateau level as a measure of the power of the muscle. In some of our cats the gastrocnemius-soleus group of muscles of each leg exerted a force of over 20 pounds (9.1 Kg.) in a single twitch.

METHOD

Briefly, the method consists in stimulating the gastrocnemius group of muscles in a cat and recording the contraction by means of a torsion lever and kymograph (fig. 1). The cat is deeply anesthetized, sodium pentobarbital being used in a dose of 0.6 cc. per kilogram of body weight, intraperitoneally, and the hindlegs are clipped free of long hair and prepared with cetylpyridinium chloride and alcohol. After this, the

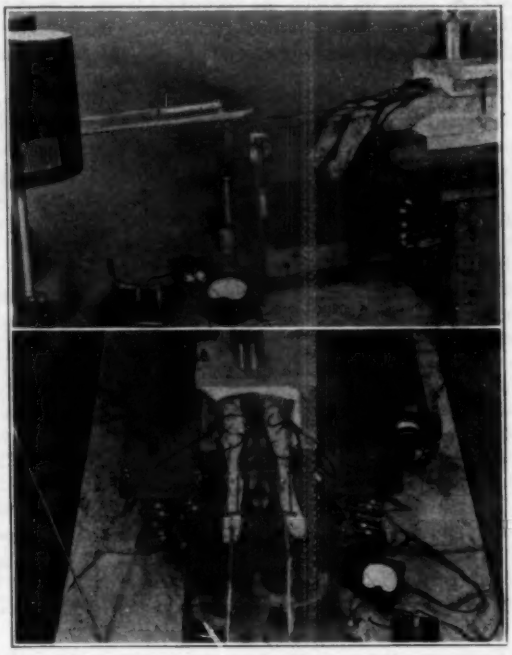

Fig. 1.—Two views of an anesthetized cat in the apparatus.

cat is mounted on the stimulating table by means of three clamps, one at each ankle and one across the pelvis and thighs.

These clamps are fastened to the same block of wood, the clamp block, which is, in turn, attached to the stimulating table. Each ankle clamp consists of a U-shaped piece of brass which, through slots, can be adjusted to various heights on the clamp block, depending on the size of the cat. Projecting centrally about ⅜ inch (1 cm.) from one arm of the U is a ⅛ inch (0.3 cm.) metal rod pointed at the end. A similar rod is screwed through the other arm of the U and is made adjustable by a thumbscrew at its end. The pelvic clamp is a plaster of paris impression of the pelvis and upper parts of the thighs of the animal, made in two pieces. One piece is a mold of the ventral side and the other a mold of the dorsal side of the animal. Each of these casts fits on two upright bolts fastened to the clamp block and can be tightened firmly around

8. Martin, E. G.; Field, J., and Hall, V. E.: A Technique for Obtaining and Recording Isometric Contraction of Mammaliam Skeletal Muscle in Situ, Am. J. Physiol. **102**:476-480, 1932.

9. Eccles, J. C.: Disuse Atrophy of Skeletal Muscle, M. J. Australia **2**:160-164, 1941.

10. Hartman, F. A., and Blatz, W. E.: Studies in Regeneration of Denervated Mammalian Muscle: III. Effects of Massage and Electrical Stimulation, J. Physiol. **53**:290-307, 1920.

the cat by means of thumbscrews. Individual pelvic clamps are made for each animal.

To mount the cat for stimulation, it is extended ventral side down on the stimulating table, with its pelvis across the ventral half of the pelvic clamp and its hindlegs in full extension. The ankle clamp pins are prepared with cetylpyridinium chloride and alcohol and firmly screwed to the tibia near the ankle. The dorsal half of the pelvic clamp is then put into place and arbitrarily tightened until it exerts as much force as when a 1,000 Gm. weight is placed on it. By means of clamping the hindlegs in full extension, any force exerted by the gastrocnemius group of muscles must act mainly on the achilles tendon and ankle joint, since movement at the knee joint is at a minimum.

Fastened firmly to the stimulating table approximately 4 inches (10 cm.) from the ankle clamps and in line with them are the torsion levers. Each of these levers consists of a heavy brass yoke across the limbs of which is bolted horizontally a piece of steel hacksaw blade on which the recording lever is mounted. The recording lever, which records its excursions on a kymograph, is tipped with celluloid and extends approximately 13¼ inches (33.6 cm.) from the center of torsion of the hacksaw blade to the tip of the lever. Since all force is exerted on the lever ¼ inch (0.6 cm.) from the center of torsion, this gives a magnification on the kymograph of 53. By means of a ¼ inch bolt screwed through one arm of the yoke and impinging against the other arm, the tension on the hacksaw blade can be varied so that the torsion lever can be adjusted to a standard. A tension such that a 200 Gm. pull on the lever registers 1 mm. on the kymograph has been arbitrarily adopted. It is thus possible by measuring the excursion of the lever on the kymograph to calculate the force exerted by the muscle. The maximum contractions achieved to date have been 48 mm. on the kymograph, which equals a $^{48}/_{53}$ mm. movement by the muscle, practically an isometric contraction. This represents a tension of 9,600 Gm. (21.1 pounds).

The force of the muscle contraction is exerted on the torsion lever by means of a brass stirrup equipped with a hook and turnbuckle at one end. A steel pin forced through the achilles tendon just proximal to the os calcis fastens to the stirrup, and the hook end is attached to the torsion lever.

There are three stimulating electrodes for each leg. Two of these each consist of Y-shaped pieces of copper wire having a half round no. 10 surgical cutting needle on each branch of the Y. One pair of needles is placed subcutaneously, one needle being inserted on each side of the leg in the region just proximal to the heads of the gastrocnemius muscle. The other pair is placed subcutaneously over the belly of the gastrocnemius muscle. Experimentally, it was found that with the electrical apparatus being used for stimulation the needle electrodes were just as effective subcutaneously as when inserted directly through the muscle. The steel pin through the achilles tendon serves as the third electrode.

A diagram of the electrical connections is shown in figure 2. Pulses of 110 volt direct current passed through the primaries of two United Transformer Corporation model S-47; 3,000 volt, center tap transformers in series furnish current for stimulation. The center tap transformer is used because it applies the same voltage to each segment of the leg from the central electrode located over the belly of the gastrocnemius group of muscles, thus helping to eliminate variation in stimulating current due to variation in resistance with slightly different positions of the electrode.

The switch used is a regular hand-operated spring key switch with platinum contact points with a 1 microfarad condenser across the gap. Platinum points were necessary in order to prevent sparking, which tended to occur with higher current strengths and which, if present, made the shock variable.

A resistance of 50,000 ohms is introduced into the circuit at each end of the secondary and at the center tap of the transformer circuit to reduce the length of the shocks so that each shock stimulates only once. It is imperative that the muscles respond to a single shock with a single twitch and do not repeat, in order to establish standard conditions in the same cat and in different cats. Without the high resistance in the secondary, it was never possible to obtain a plateau of maximal contraction because with the low resistance of the leg the shocks were so long that they were stimulating more than once. Oscillograph pictures showed that without the resistance the break shock falls to half value in approximately 0.05 second, and it is known that mammalian muscle can respond at least once approximately every 0.005 second. With the high resistance, the half-value duration of the

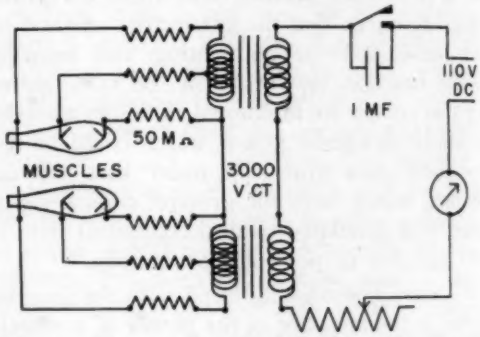

Fig. 2.—Diagram of stimulator. Each transformer is a United Transformer Corporation, 3,000 volt, center tap, model S-47. Each resistance in output of transformer is 50,000 ohms.

make shock is cut to approximately 0.0085 second and the break shock to approximately 0.005 second, and a plateau can be obtained.

After the cat has been arranged on the stimulating table with the electrodes in place, the torsion levers are connected and tightened by means of the turnbuckle until they are foreloaded 800 Gm. After this, the muscles are stimulated in single makes and breaks over a series of current strengths until the maximal single twitch contraction break plateau is obtained.

Records obtained from normal innervated legs with this stimulating apparatus follow a definite pattern (fig. 3). At lower primary current strengths, around 0.4 to 1 ampere, the make contraction is lower than the break contraction, but with increasing amperage, usually by 1 ampere, the make equals the break. As the amperage is increased still further, the make exceeds the break, but the break continues to remain approximately the same height as when first equaled by the make, even with stimulation cur-

rents as high as 4 to 5 amperes. This gives a plateau for the break twitch response, extending over a stimulation range of approximately 3 to 4 amperes, which we take as the maximal single twitch response. The effective stimulus in the innervated muscle is presumably exerted on the nerves or nerve endings.

The twitch was used instead of a tetanic contraction because it is more economical of the animals' strength. The whole series of contractions necessary to determine the maximal twitch response can be obtained without fatiguing the muscle as much as is necessary for one tetanic stimulation. The twitch is not a measure of the greatest force that the muscle can exert but is one measure of power. We assume that the electrical stimulus if of equal amperage, whether it be for a twitch or a tetanic response, involves the same number of muscle fibers because spread of current is the same, and therefore the twitch response and the response to the first stimulus of the tetanic series are equal. Thus, differences in strength thereafter are due to summation rather than to any increased number of muscle fibers responding to stimulation, and the twitch may be regarded as a constant fraction of the tetanic response. If the same electrical apparatus is always used to obtain the twitch response, then the twitch should always remain the same fraction of the tetanic contraction. Another reason for not using the tetanic stimulation was that it was not possible to obtain an inductorium which would stimulate rapidly enough to produce a smooth tetanus at the necessary current strengths without great sparking at the contact points, thus producing a current whose strength and length were inconstant.

Following this procedure we have stimulated cats as much as twelve different times without noticeable ill effects. The wounds made by the ankle clamp heal within one week without infection, and the pin through the tendon produces only inflammation of a chronic type. Of the total of 70 cats stimulated at least three times in this series of experiments, none showed any suppuration or debilitating injury to the achilles tendon or to the distal end of the tibia, even though 26 of these cats were stimulated nine or more times.

OBSERVATIONS ON NORMAL MUSCLES

A satisfactory apparatus having been constructed, a group of large cats in excellent general condition were obtained, and the strength of a single twitch of each gastrocnemius-soleus group of muscles was determined at the plateau level of electrical stimulation. These observations were repeated at weekly intervals, and after we had mastered the technic of the experiment there was satisfactory uniformity in the results of the tests as long as the animals remained in good health. We accepted a weekly maximum variation from the mean of less than 10 per cent in the strength of the twitch as satisfactory.

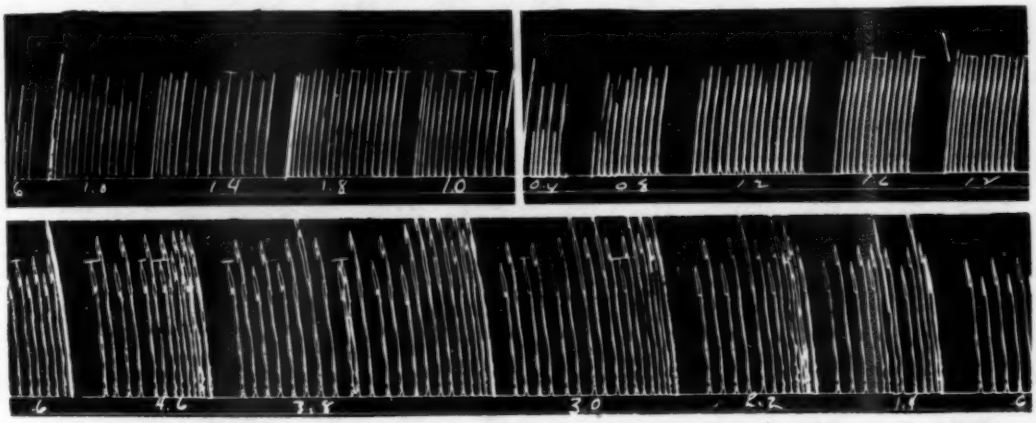

Fig. 3.—Record of twitch height in normally innervated muscles: upper, two normal stimulation patterns; lower illustration of amperage range for plateau twitch height. The plateau height is noted by compass marks. Amperage of stimulation current listed below each group of twitches. Final twitch in each group is due to break shock.

Since it is possible by this method to obtain records of muscles which week after week vary less than 10 per cent from the mean, we believe that the method gives us a satisfactory index of the strength of the muscle at the time of testing.

The experimental legs in the last 51 animals stimulated showed only 4.6 per cent average maximum deviation from the mean normal twitch strength, with a range of 0 to 8.3 per cent, while

the control legs, those with the greater maximum deviation from the mean normal twitch strength, had an 8.6 per cent average maximum deviation, with a range of 1 to 23.4 per cent. In these 51 animals the mean normal twitch strength in the control leg varied from that in the experimental leg by an average of 8.7 per cent, with variations of 0.5 to 34.3 per cent. There was no tendency for the right legs to be stronger than the left or vice versa.

This method of stimulating and recording contraction of the gastrocnemius group of muscles in the cat was also applied to the study of atrophy of disuse and of denervation.

Records obtained at the time of removal of the cast showed a loss of strength in the gastrocnemius group of muscles of approximately 90 per cent in the relaxed cat, 10 per cent in the cat in the stretched position and 0 per cent in the cats in the neutral position. Results for the group in the neutral position were invalidated because, owing to cracking of the cast, immobilization had not been complete. It was possible to follow the relaxed leg and one neutral leg with weekly stimulations for one month, and at the end of this time the relaxed leg showed approximately 60 per cent recovery of the original strength and the neutral leg remained the same.

TABLE 1.—*Mean Normal Twitch-Strength for Disuse Atrophy Cats (Second Study)*

	Left Leg						Right Leg						
Cat	Trial 1, %	Trial 2, %	Trial 3, %	Trial 4, %	Maximum Deviation, %	Mean Normal Twitch Strength, %	Trial 1, %	Trial 2, %	Trial 3, %	Trial 4, %	Maximum Deviation, %	Mean Normal Twitch Strength, %	Varition in Mean Normal Twitch Strength Between Control and Experimental Legs, %
55	19.0*	32.5	27.5	25.5	9.5	28.5	24.0*	30.5	30.5	35.5	6.9	32.1‡	11.2
59	35.0	36.5	31.0*	36.0	1.7	35.8‡	37.5	32.0	34.0	29.0*	5.8	34.5	3.6
62	34.0	36.0	35.5	....	2.2	35.1‡	33.5	32.5	29.5	....	5.0	31.8	9.4
69	32.5	30.5	29.0	....	4.0	30.7	33.0	33.5	33.5	....	0.6	33.3‡	7.9
72	38.0	43.0	42.5	....	5.1	41.1‡	41.0	41.5	33.0	....	7.0	38.5	6.3
73	30.0	30.0	28.0	....	3.1	29.3	32.0	27.5	30.5	....	4.3	30.0	2.4
74	31.0	31.0	34.5	....	7.1	32.2	36.0	32.0	36.0	....	7.8	44.7‡	7.2
75	34.0	30.5	39.5*	35.5	5.7	33.3	33.0	34.5	39.0*	33.5	1.8	33.7‡	1.2
76	35.0	30.0	34.0	....	6.1	33.0	27.5	28.5	29.0	....	2.5	28.1‡	17.4
77	31.0	23.0	24.5	....	12.2	26.2	30.0	30.0	30.0	....	0.0	30.0‡	12.7
78	35.5	35.5	35.5	....	0.0	35.5‡	42.5	37.5	37.5	....	8.4	39.2	10.4
82	40.0	38.0	31.5	....	8.2	36.5	35.0	34.0	31.0	....	5.2	33.0‡	10.6
83	28.0	29.0	31.5	....	6.8	29.5	44.5	47.0	43.0	....	4.9	44.8‡	34.3
84	31.0	31.0	27.0*	32.0	2.2	31.3‡	35.0	33.0	28.5	43.5*	11.5	32.2	6.1
87	29.5	25.5	27.0	....	8.1	27.3	29.5	27.0	29.0	....	5.3	28.5‡	4.2
88	36.5	41.5	40.5	....	7.6	39.5‡	38.5	47.0	45.0	....	11.5	43.5	10.1
54	38.0	37.5	34.0	....	6.8	36.5	38.0	38.5	36.5	....	2.9	37.6‡	2.9
56	35.5	27.0*	29.0*	35.0			36.5	20.5*	24.0*	29.5*			
	Trial 5.....		33.0				Trial 5.....		38.0				
	Trial 6.....		41.5*		5.2	34.8	Trial 6.....		41.5*		3.4	37.8‡	7.9
	Trial 7.....		35.5				Trial 7.....		39.0				

* Value not used because of obvious discrepancy.
‡ Leg which was immobilized.

OBSERVATIONS ON DISUSE ATROPHY

The studies on disuse atrophy were designed to determine which position of immobilization brought about the least atrophy of the muscle group.

The first study consisted of a series of experiments on 19 cats whose gastrocnemius group of muscles were stimulated once a week for three to four successive weeks so as to establish a mean normal value. Immediately after the final stimulation, the left hindlegs were immobilized in neutral, relaxed and stretched positions by means of castex bandages. For the relaxed position, the casts were applied with the knee flexed and the foot straight (plantar flexion). For the stretched position, the casts were applied with the knee straight and the foot in a position of dorsiflexion. For the neutral position, the casts were applied with the knee in semiflexion and the foot in semidorsiflexion. Only 4 animals survived the eight week period of immobilization: 1 in the relaxed, 1 in the stretched and 2 in the neutral position.

The high mortality of the animals in this experiment was due to the inanition and infection which followed development of ulcers under the casts. This condition was attributed to two factors: (1) the too early application of the cast while wounds on the legs incurred in stimulation were unhealed and (2) the combined irritating action on the skin of the iodine used in preparing the leg for stimulation just before immobilization and, possibly, the castex bandage or our lack of skill in using it.

In the second study on disuse, 22 cats were used and the procedure modified in an attempt to decrease the incidence of ulceration and gangrene. After the animals had been stimulated as before to obtain a mean, an interval of one week was allowed for healing of the leg wounds before casting. Casting material was

TABLE 2.—*Muscle Strength in Disuse Atrophy Cats Following Removal of Cast (Second Study)*

Immobilized leg is listed first; control leg, second.

	Cat	Leg	Mean Normal, %	Maximum Deviation from Mean Normal, %	First Week After Cast Removed, %	Second Week After Cast Removed, %	Third Week After Cast Removed, %	Fourth Week After Cast Removed, %	Sixth Week After Cast Removed, %	Eighth Week After Cast Removed, %	Ninth Week After Cast Removed, %
Relaxed	55	R	32.1	6.9	29.0	33.0	35.0	35.0	32.0	Died	
		L	28.5	9.5	37.5	32.5	39.5	33.0	33.0	Died	
	59	L	35.8	1.7	35.0	34.0	36.0	41.0	33.5	34.5	
		R	34.5	5.8	37.5	39.5	33.5	41.5	34.0	33.5	
	69	R	33.3	0.6	29.0	32.0	34.0	32.0	31.5	34.0	
		L	30.7	4.0	36.5	37.5	36.0	35.0	33.5	40.5	
	72	L	41.1	5.1	45.0	35.5	45.5	39.0	40.5	36.5	
		R	38.5	7.0	52.5	45.0	48.0	46.0	36.5	42.5	
	73	L	29.3	3.1	26.5	26.5	29.0	31.5	28.5	27.5	
		R	30.0	4.3	33.0	32.5	34.0	35.5	27.5	30.5	
	76	R	38.1	2.5	29.5	30.5	40.5	35.0	34.5	Died	
		L	33.0	6.1	39.0	36.5	40.0	43.5	38.0	Died	
	77	R	30.0	0.0	16.5	20.5	27.5	27.0	26.5	24.5	
		L	26.2	12.2	26.5	31.5	36.5	35.0	30.0	26.0	
	82	R	33.0	5.2	26.0	30.5	34.0	32.0	32.0	Died	
		L	36.5	8.2	38.0	37.0	41.5	39.0	36.0	Died	
Stretched	62	L	35.1	2.2	24.5	29.5	27.0	28.0	Died		
		R	31.8	5.0	41.5	41.5	37.5	33.0	Died		
	74	R	34.7	7.8	32.0	36.0	37.5	32.0	27.0	27.5	
		L	32.2	7.1	28.0	35.0	31.5	35.0	34.5	31.5	
	75	R	33.7	1.8	29.5	35.0	35.0	33.5	18.5	23.0	
		L	33.3	5.7	32.0	40.0	32.0	36.5	32.0	34.5	
	78	L	35.5	0.0	25.5	27.5	25.0	25.0	26.5	29.0	
		R	39.2	8.4	40.5	41.5	40.5	44.0	45.0	40.0	
	83	R	44.8	4.9	27.5	33.0	32.0	35.5	32.0	29.0	
		L	29.5	6.8	40.5	36.0	35.0	39.5	34.0	30.5	
Neutral	54	R	37.6	2.9	34.0	37.0	35.0	27.0	27.0	....	27.5
		L	36.5	6.8	33.0	36.5	32.5	28.0	34.0	....	36.5
	56	R	37.8	3.4	26.0	31.0	28.5	32.0	30.0	....	32.5
		L	34.8	5.2	39.0	38.5	38.0	37.5	33.5	....	42.5
	84	L	31.3	2.2	41.0	46.5	36.5	36.0	33.0	....	33.5
		R	32.2	11.5	46.0	47.5	41.5	35.0	39.5	....	33.5
	87	R	28.5	5.3	29.0	33.0	30.0	Died			
		L	27.3	8.1	38.5	32.0	27.5	Died			
	88	L	39.5	7.6	42.5	45.5	41.0	41.5	42.5	....	30.0
		R	43.5	11.5	47.5	48.0	49.0	50.0	44.0	....	36.0

TABLE 3.—*Significant Variation of Muscle Strength from the Mean Normal Following Cast Removal in Disuse Atrophy Cats (Second Study)*

	Cat	Mean Normal Twitch Strength of Immobilized Leg	Maximum Deviation from Mean Normal, %	Actual Maximum Deviation from Mean Normal	Variation in Excess of Maximum Deviation: First Week After Cast Removed, %	Second Week After Cast Removed, %	Third Week After Cast Removed, %	Fourth Week After Cast Removed, %	Sixth Week After Cast Removed, %	Eighth Week After Cast Removed, %	Ninth Week After Cast Removed, %
Relaxed	55	32.1	6.9	2.2	— 2.8	.....	+ 2.2	+ 2.2	.....	Died	
	59	35.8	1.7	0.6	— 0.6	— 3.4	.....	+12.8	— 7.5	— 1.2	
	69	33.3	0.6	0.2	—12.4	— 3.3	+ 1.5	— 3.3	— 4.8	+ 1.5	
	72	41.1	5.1	2.1	+ 4.4	— 8.5	+ 5.6	.....	.....	— 6.1	
	73	29.3	3.1	0.9	— 6.5	— 6.5	.....	+ 4.4	.....	— 3.1	
	76	38.1	2.5	0.7	+ 2.5	+ 6.0	+41.6	+22.0	+20.3	Died	
	77	30.0	0.0	0.0	—45.0	—31.6	— 8.3	—10.0	—11.7	—18.3	
	82	33.0	5.2	1.7	—16.1	— 2.4	.....	.....	.....	Died	
				Average	— 9.6	— 6.2	+ 5.3	+ 3.5	— 0.5	— 5.4	
Stretched	62	35.1	2.2	0.8	—28.9	—13.7	—20.8	—18.0	Died		
	74	34.7	4.9	1.7	— 2.9	.....	+ 3.2	— 2.9	—17.3	—15.9	
	75	33.7	1.8	0.6	—10.7	+ 2.1	+ 2.1	.....	—43.3	—30.0	
	78	35.5	0.0	0.0	—28.2	—22.6	—29.6	—29.6	—25.3	—18.3	
	83	44.8	2.1	1.4	—35.5	—23.2	—25.4	—17.6	—25.4	—32.2	
				Average	—21.1	—11.5	—14.1	—13.6	—27.8	—24.1	
Neutral	54	37.6	2.9	1.1	— 6.6	.....	— 4.0	—25.3	—25.3		—23.9
	56	37.8	3.4	1.3	—27.8	—14.6	—21.2	—11.9	—17.2		—10.6
	84	31.3	2.2	0.7	+28.8	+46.4	+14.4	+12.8	+ 3.2		+ 4.8
	87	28.5	5.3	1.6	.....	+10.5	.....	Died			
	88	39.5	7.6	3.0	.....	+ 7.6	.....	.....	.....		—16.5
				Average	— 1.1	+10.0	— 2.2	— 6.1	— 9.8		—11.5

..... indicates variation not in excess of actual maximum deviation.

changed to regular plaster of paris bandages padded at pressure points with cottonoid, and just before application of the cast sulfanilamide powder was dusted over the leg and between the toes. The leg of each animal which showed the lesser maximum deviation from the normal mean was the one chosen for immobilization, and in order to be used this deviation had to be below 10 per cent. These data for 18 typical cats are summarized in table 1. With these modifications, 18 of the 22 cats withstood a six week period in the cast, 8 in the relaxed, 5 in the neutral and 5 in the stretched position. One week was allowed after removal from the cast for reestablishment of normal joint action and subsidence of edema before the initial stimulation was made. Records were obtained once a week for the first four weeks after removal of the cast and every two weeks after that for a total of eight weeks. Thirteen cats were followed for the entire eight week period and 3 cats for six weeks. Data appear in table 2 and are represented graphically in figure 4.

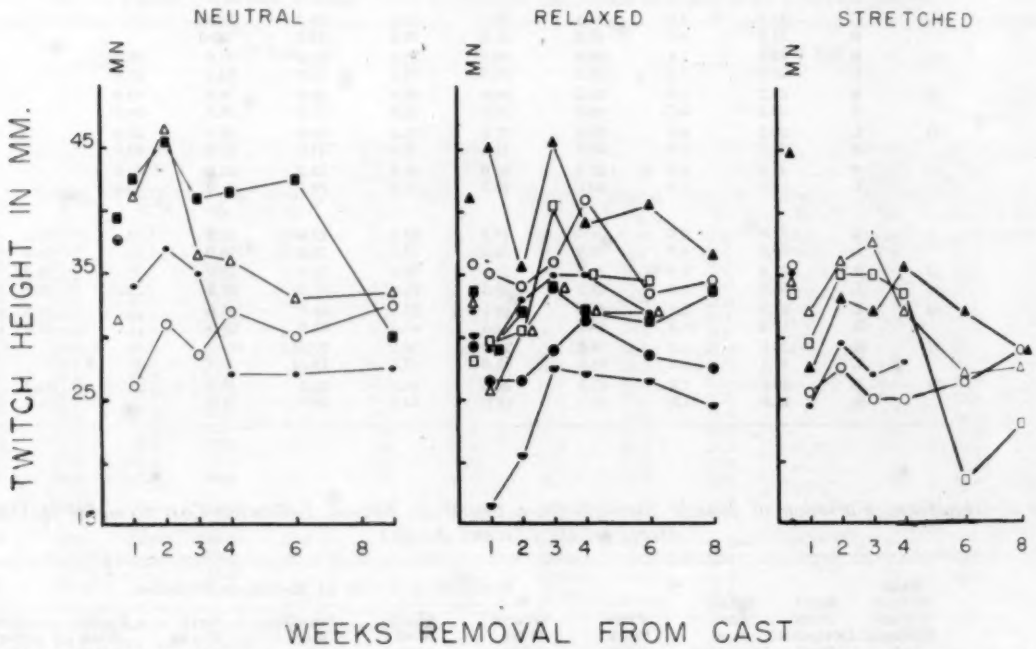

Fig. 4.—Graph showing twitch height in disuse atrophy of muscles following removal from cast. Symbols in column under *M N* represent mean normal twitch height for each animal. Each symbol represents a different cat.

The significant variation from the mean normal twitch strength is summarized in table 3. This is taken as that variation from the mean normal twitch strength which is in excess of the maximum deviation from the mean normal and is calculated as per cent of mean normal twitch strength. Taking the average for the groups, these data show that one week after removal of the cast the neutral legs showed no loss of strength while the relaxed legs had lost approximately 10 per cent and the stretched legs 20 per cent and that the stretched group remained consistently below the mean normal value. Analysis of the data for each cat in all the groups, however, shows a great individual variation both between members of the group and between individual stimulations of the same animal. Because of this variation, there is no consistent loss or gain in strength in the groups in the neutral or in the relaxed position. If the great loss of cat 77 and the gain of cat 76 are omitted, the group in the relaxed position shows little significant variation from the mean normal value. In the group in the neutral position the reason for the gain in strength of cat 84 and the pronounced loss of strength terminally of cat 54 is not apparent. On the other hand, all 5 of the animals in the stretched position showed significant loss in the first week and remained below the mean normal value for the whole period of stimulation, whereas, of the 5 animals in the other groups showing significant loss of strength in the first week, 3 had returned to approximately normal by the end of the second week and 4 by the end of the third week. These data then indicate that six weeks' immobilization of normal muscles in the stretched position brings about moderate and persistent disuse atrophy, whereas immobilization in the neutral and in the relaxed position has little consistent effect, and that the relaxed position is no more conducive to disuse atrophy than is the neutral position.

It is to be noted that in this group the first tests were done one week after the casts were

removed. This gave time for the muscle to regain its tone, for its circulation to return to an approximately normal condition and for the joints to limber up. We recognize the fact that there was some recovery of power in the muscles during this week but believe that the tests made immediately after the removal of the immobilization are apt to give false impressions, and this is especially true of a muscle which has been immobilized in a position of relaxation.

Further analysis of the data presents several difficulties. The degree of variation of strength from one stimulation to the next in the same animal is unexplained. It is difficult to believe that it is due to a technical error on the part of the operator, since the same technic of stimulation was observed after immobilization as before. The average maximum variation from the mean in at least three stimulations before immobilization was only 4 per cent in this group and, as stated before, in a total of 51 cats not more than 4.6 per cent. Furthermore, it is peculiar that in 3 cats the muscles showed an increase in strength following immobilization.

OBSERVATIONS ON DENERVATED MUSCLES

The studies on denervation were carried out with the idea of determining whether immobilization had any effect in delaying or lessening the atrophy of denervation and, if so, which position was the most effective.

In 24 cats the mean normal twitch in the strength of muscles was determined by at least three stimulations one week apart, and for an animal to be used the maximum deviation from the mean had to be less than 10 per cent. The leg which showed the least deviation from the mean was chosen for denervation. This was carried out by sectioning the sciatic nerve at the level of the ischial tuberosity and suturing the two ends back under the muscle so that they were directed away from each other. At the conclusion of the experiment when the gastrocnemius muscles were dissected free and weighed, the area of nerve section was carefully inspected and no evidence of union found in any of the animals, the ends of the nerve being in most cases ½ to ¾ inch (1.2 to 1.9 cm.) apart.

Twelve of these animals were denervated and not immobilized. These controls were stimulated once a week in order to determine the normal course of atrophy measured by our apparatus. Nine of the animals were followed for six weeks or more and 6 of them for as long as ten weeks. The other 12 animals were denervated and immobilized immediately for a period of six weeks, 6 in the stretched and 6 in the relaxed position. Another 6 would have been immobilized in the neutral position, but the control group had shown our method to be unreliable for stimulation of denervated muscle.

Denervation of muscle increases the time-strength characteristic (chronaxia), as shown by Adrian [11] (1916). Therefore the denervated legs were stimulated with only 20,000 and 30,000 ohms in the secondary, thus producing a longer-acting stimulus. Still no definite plateau could be obtained consistently. Sometimes a plateau from 3.8 to 5 amperes could be recorded, while at other times no plateau could be found even up to 5 amperes (fig. 5). This applied to stimulation of an individual muscle from week to week as well as to the group as a whole. We attributed this inability to obtain a plateau in the denervated muscles to several factors. With denervated muscle, excitation is entirely through the muscle fibers and, in contrast to the disuse atrophy muscles, no nerve stimulation occurs.

Fig. 5.—Record of twitch height in denervated muscles. Upper and middle records show no plateau. Lower record shows plateau from 3.4 to 5 amperes. Plateau height denoted by compass marks. Stimulation amperages listed below each group.

11. Adrian, E. D.: The Electrical Reaction of Muscles Before and After Nerve Injury, Brain **39**:1-33, 1916.

The muscle itself requires a longer period of stimulation before reacting to the current, as mentioned before. The mass of muscle was so great and the spread of the exciting current so nonuniform that high current strengths were necessary before all the muscle fibers could be reached. When these current strengths were used, they were so great that the fibers closest to the electrodes were being overstimulated and, in fact, responded more than once to each shock. Shortening the duration of shock sufficiently to prevent this required unmanageable amperages that caused arcing at the switch.

Realizing these limitations of the data, the plateau values or, in the many cases in which plateaus were not obtained, the highest contraction recorded with amperages up to 5 amperes were analyzed. Amperages of 3.8 or higher had to be used almost exclusively. These data show that of the control group five muscles after six weeks' denervation and four muscles after seven weeks' denervation each lost 29.4 per cent of their original strength. These nine muscles had lost an average of 21.9 per cent of their strength at the end of only one week's denervation, which would seem to indicate that not all the muscle fibers were being stimulated, or if they were it indicates an immediate loss of strength on denervation of muscle followed by a much more gradual loss. Even if not all the fibers are stimulated, the loss in strength from 21.9 per cent to 29.4 per cent in six weeks' denervation may indicate the speed of the change occurring in the muscle, because the current spread is the same and the same proportionate number of fibers would be reached with each stimulation. In the groups which were denervated and then immobilized six weeks, those muscles immobilized in the relaxed position showed an average loss in strength of 73.6 per cent in 3 cases and those immobilized in the stretched position lost approximately 51.8 per cent in 5 cases.

In the denervated animals, the loss in wet weight after seven weeks' denervation was practically the same in each of the three groups studied. By comparing the wet weight of the denervated muscle to that of the normal muscle, we found that the control group lost 63 per cent in 3 animals, the group which was so immobilized in a stretched position 61.6 per cent in 4 animals, and the group immobilized in relaxed position 55.9 per cent in 3 animals. This approximately equal loss in weight of the three groups does not correspond to their pronounced difference in loss of power and is further support for the feeling that the loss in wet weight of a denervated muscle is not a reliable criterion for judging its loss in power.

COMMENT

We believe that the method of recording and determining the strength of a single contraction (twitch) in the gastrocnemius-soleus group of muscles at the break plateau level is a satisfactory method of determining the power of this muscle at intervals in the living animal. By this method it is possible to establish a normal for a given muscle and then to determine the strength of a single twitch of the same muscle after it has been immobilized.

Our experiments on disuse atrophy were not very satisfactory because of difficulty in maintaining the animals in good condition and in maintaining satisfactory immobilization over the desired period of six to eight weeks. (As a matter of fact, we used over 90 animals in these experiments and only results for the last groups are recorded.) From our data it seems that immobilization of an extremity over a reasonable period is not greatly detrimental to normal muscles unless they are immobilized in a stretched position. It is further to be noted that these muscles quickly recover their normal power spontaneously when set free and permitted to function, and no physical therapy is necessary. Admittedly, our immobilization was not absolute, but neither is that used clinically in plaster casts or splints.

Of the three positions used, the relaxed and neutral positions were less harmful and the stretched position was more harmful, and this conforms with our clinical observations in the past.

We realize the inadequacy of our experiments on denervated muscles and the danger of drawing conclusions from inadequate data, but it is our impression that prolonged immobilization in any position is more harmful to denervated muscles than to normal muscles. We believe that the danger of "stretch paralysis" in extremities which are not immobilized has been overemphasized and that the paralyzed muscle is better left unsplinted, unless splints are necessary to relieve pain, to prevent deformity or to aid function in permanently paralyzed extremities.

In line with this reasoning is the question of priority in fractures of the extremities complicated by peripheral nerve lesions. We believe that when possible the nerve should be repaired without waiting for the fracture to heal or even for the infection in the bone to heal or be eradicated. With the aid of chemotherapy, this can

be done with relative safety. We further believe that when practical internal fixation should be used for fractures complicated by nerve lesions in order that external fixation may be reduced to a minimum. For this, there may be a place for the dual plates recently described by one of us (J. A. K.).

During the course of the work, we have thought of several means to improve the method and to eliminate obstacles which were encountered. Since we cannot effect them at this time, we make them as suggestions to any one interested in carrying this work further.

1. In denervated muscle, a satisfactory plateau could probably be obtained on stimulation if smaller experimental animals were used. The main factor in our inability to obtain this plateau was the size of the muscle which was so great in cats that stimulation of all the muscle fibers required current strengths which stimulated the fibers nearest the electrodes more than once. The smaller the muscle mass, the less important this factor would be.

2. Arcing across the points of the hand switch was another difficulty. A thyrotron would eliminate this, give better control of stimulating currents and make possible their use at much higher values acting for a shorter time. It could also be set to deliver a standard number of stimuli at each current strength used, thus eliminating excess stimulation and any fatigue factor which that may introduce.

3. The twitch measures immediate power but gives no indication of endurance. A study of tetanic strength in disuse and denervation atrophy may yield important information. Such a study was not possible with our apparatus because the inductorium could not carry the necessary current strength. A thyrotron, however, would provide a means for constant strength tetanic stimulation at high currents.

SUMMARY

This study attempts to determine two things: (1) the optimum position of fixation of limbs in order to conserve muscle power and (2) the best method of treatment of muscles paralyzed by loss of nerve supply.

A review of the literature on muscle physiology shows that in most of the studies of disuse and denervation atrophy weight has been used as a criterion of the atrophy. Functional studies have employed methods requiring the killing of the animal after one stimulation. Only one functional study has been reported in which the same animal was repeatedly stimulated, and this method was not satisfactory for our purpose.

A method was developed for recording the twitch strength of the gastrocnemius-soleus group of muscles in cats. By means of the described method, animals have been stimulated as much as twelve different times without noticeable ill effect.

In a series of 51 normal cats stimulated at weekly intervals, this method yielded normal values for one leg, which showed only 4.6 per cent average maximum deviation from the mean, with a maximum deviation range of 0 to 8.3 per cent.

This method was applied to the study of disuse atrophy. After normal values were determined legs were immobilized for six weeks, with the muscle group in stretched, relaxed and neutral positions. Stimulation for eight weeks following removal of the cast showed moderate and persistent disuse atrophy in the muscles which were stretched, whereas the relaxed and neutral groups showed little consistent effect.

Denervated cats also were immobilized in various positions, but the study was unsatisfactory because no definite contraction plateau could be obtained in response to stimulation.

On the basis of the data obtained from denervated cats, however, the suggestion is made that denervated muscles atrophy less if left alone than if immobilized. Emphasis is also placed on repairing the nerve before the bone is healed when fractures are complicated by peripheral nerve injuries.

Dr. George Bishop, Professor of Biophysics, Washington University School of Medicine, has given help, without which this method could not have been developed.

Clarence E. Rupe, M.D., has given technical assistance in some of these experiments.

REESTABLISHMENT OF PANCREATIC SECRETION INTO THE INTESTINE AFTER DIVISION OF THE PANCREAS

AN EXPERIMENTAL STUDY

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Since 1935 much progress has been made in the radical operative treatment of carcinoma involving the head of the pancreas and the periampullary region. In that year the publication of Whipple, Parsons and Mullins [1] opened an avenue of approach to a technical field which previously had been entered only at sporadic intervals. Numerous contributions to the technical details of the operation have appeared in the literature of recent years, and complete reviews of their development have been recorded.[2] As a result, the matter of pancreatic and periampullary carcinoma can be approached today with a clearer conception of the operative technic and with a reasonable chance of accomplishing a surgical cure. Despite widening experience with this difficult surgical problem, however, the incidence of postoperative complications, some of which are fatal, remains high. Some of the more distressing postoperative sequelae are referable to the stump of the divided pancreas and consist of external pancreatic fistula, acute pancreatic necrosis, retention cyst and chemical, or "enzymatic," peritonitis.

The pancreatic stump has been handled, generally speaking, by one of two methods: occlusion by inverting sutures, with or without ligation of the duct of Wirsung, or some form of pancreaticoenterostomy, in which the stump is implanted into a segment of intestine. As regards the first method, digestion of the inverting sutures occurs all too frequently, with resultant leaking of pancreatic juice and the consequent development of one or more of the aforementioned complications. Concerning the second method, the question has been raised whether reimplantation of the pancreatic duct into the gastrointestinal tract is actually necessary, inasmuch as it is well established that many patients live normal, healthy lives after being deprived of the external secretions of the pancreas. On the contrary, numerous persons in whom the continuity of the pancreaticointestinal relationships has been disrupted suffer severely from disturbances of fat digestion in the form of steatorrhea and malnutrition. In their discussion of this matter, Pickrell and Blalock [3] concluded that whenever possible pancreatic secretions should be preserved by implantation of the duct into the bowel. Child [4] has stated that "the significant single fact is that it cannot be fore-

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1. Whipple, A. O.; Parsons, W. B., and Mullins, C. R.: Treatment of Carcinoma of the Ampulla of Vater, Ann. Surg. **102**:763, 1935.

2. (*a*) Whipple, A. O.: Surgical Treatment of Carcinoma of the Ampullary Region and Head of the Pancreas, Am. J. Surg. **40**:260, 1938. (*b*) Hunt, V. C.: Surgical Management of Carcinoma of the Ampulla of Vater and of the Periampullary Portion of the Duodenum, Ann. Surg. **114**:570, 1941. (*c*) Orr, T. G.: Resection of the Duodenum and Head of the Pancreas for Carcinoma of the Ampulla, Surg., Gynec. & Obst. **73**:240, 1941. (*d*) Trimble, I. R.; Parsons, J. W., and Sherman, C. P.: A One-Stage Operation for the Cure of Carcinoma of the Ampulla Vater and Head of the Pancreas, ibid. **73**:711, 1941. (*e*) Whipple, A. O.: The Rationale of Radical Surgery for Cancer of the Pancreas and Ampullary Region, Ann. Surg. **114**:612, 1941. (*f*) Pearse, H. E.: A Simplified Anastomosis for Resection of the Duodenum and Head of the Pancreas, Surg., Gynec. & Obst. **75**:333, 1942. (*g*) Harvey, S. C., and Oughterson, A. W.: The Surgery of Carcinoma of the Pancreas and Ampullary Region, Ann. Surg. **115**: 1066, 1942. (*h*) Brunschwig, A.: The Surgery of Pancreatic Tumors, St. Louis, C. V. Mosby Company, 1942; (*i*) One-Stage Pancreaticoduodenectomy, Surg., Gynec. & Obst. **77**:581, 1943. (*j*) Child, C. G., III: Carcinoma of the Duodenum: One-Stage Radical Pancreaticoduodenectomy Preserving the External Pancreatic Secretion; Case Report, Ann. Surg. **118**:838, 1943. (*k*) Cattell, R. B.: Resection of the Pancreas: Discussion of Special Problems, S. Clin. North America **23**:753, 1943; (*l*) Radical Pancreaticoduodenal Resection for Carcinoma of the Ampulla of Vater, ibid. **24**: 640, 1944.

3. Pickrell, K. L., and Blalock, A.: The Surgical Treatment of Carcinoma of the Common Bile Duct, Surgery **15**:923, 1944.

4. Child, C. G., III: Pancreaticojejunostomy and Other Problems Associated with the Surgical Management of Carcinoma Involving the Head of the Pancreas, Ann. Surg. **119**:845, 1944.

cast prior to operation to which group any given patient will ultimately belong" and, consequently, advocated maintenance of the external secretory function of the pancreas. Further support to the importance of preserving the pancreatic juice has been given recently by Whipple.[5]

When one has adopted the idea that some variety of pancreaticoenterostomy is desirable, the problem arises of developing a satisfactory technic. Experimentally, several methods have been applied, beginning in 1909 with the complicated procedure of Coffey.[6] In 1915 Sweet and Simons[7] described a method of implantation of the divided pancreatic stump of a dog into the small intestine, while Patrie, Pyle and Vale[8] in 1917 reported a similar procedure on dogs, with a satisfactory functional result. More recently, Person and Glenn[9] demonstrated the feasibility of implanting the pancreatic stump into the stomach by open anastomosis in dogs. Their results indicated that pancreaticogastrostomy produces a normally functioning fistula and that in such a situation atrophy of the pancreas, acute pancreatitis, peritonitis and deposition of lipids in the liver do not occur. Extending the matter of pancreaticoenterostomy further, Poth,[10] Child[4] and Cattell[2k] each have applied some form of the procedure in clinical practice, with satisfactory results.

An evaluation of the technics employed by the aforementioned investigators directs attention to two important factors: with the exception of Cattell's[2k] simple method, all procedures involve an open anastomosis, thereby causing a breach in asepsis, and most are too time consuming, even though mechanically simple. The radical operative treatment of periampullary and pancreatic carcinoma is a formidable test of the patient's endurance, and the conservation of time may be an important factor in the ultimate outcome. Inasmuch as the disposal of the pancreatic stump represents a terminal step in the procedure, when the patient's vitality is lowest, the method of managing this technical detail should be uncomplicated and quickly performed. As regards asepsis, it is advisable to avoid, if possible, opening the intestine in the presence of the large raw surface created by duodenectomy. With the idea in mind of developing an aseptic technic which can be performed with minimal loss of time and by which the external pancreatic secretions can be preserved, the following experimental study was conducted.

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6. Coffey, R. C.: Pancreatic-Enterostomy and Pancreatectomy: A Preliminary Report, Ann. Surg. **50**: 1238, 1909.

7. Sweet, J. E., and Simons, I. H.: Some Experiments on the Surgery of the Pancreas, Ann. Surg. **61**: 308, 1915.

8. Patrie, H. H.; Pyle, L. A., and Vale, C. F.: Recent Experimental Studies of the Pancreas, Surg., Gynec. & Obst. **24**:479, 1917.

9. Person, E. C., Jr., and Glenn, F.: Pancreaticogastrostomy, Arch. Surg. **39**:530 (Oct.) 1939.

10. Poth, E. J.: The Implantation of the Pancreatic Duct into the Gastrointestinal Tract, Surgery **15**:693, 1944.

METHOD

Twenty-two dogs were studied. Fifteen were subjected to operation under anesthesia induced by intravenous injections of pentobarbital sodium by the following technic. The duodenum was delivered into the wound along with the attached pancreas. The gland was divided at the junction of the uncinate process and the body without disturbing the relationships of the latter to the duodenum (fig. 1 *A*), thereby leaving intact the junction of the main pancreatic duct with the ampulla of Vater. The exposed transected surface of pancreatic body was closed by interrupted invaginating sutures of fine silk after ligation of the divided duct (fig. 1 *A*). In this manner, the long uncinate process (10 to 15 cm.) was isolated entirely from the remainder of the gland, maintaining its independent blood supply intact. No attempt was made to ligate the divided end of the uncinate duct, but it was allowed to retract into the parenchyma of the gland (fig. 1 *B*). A loop of jejunum about 7 inches (17.7 cm.) from the ligament of Treitz was next brought into the wound. In the long axis of the antimesenteric surface of the jejunal loop, an incision was made of sufficient length to accommodate the cut surface of the uncinate stump. Particular care was taken to carry the incision down to, but not through, the mucosa, so that an opening into the lumen would not occur. The serosal edges of the incision were spread apart gently, and the stump of the divided uncinate process, with its retracted duct, was implanted into the jejunal wall and made secure by interrupted sutures of fine surgical gut (fig. 1 *C*). The abdominal wound was closed in layers.

The remaining 7 animals were operated on by a modification of the technic of Cattell.[2k] The procedure was similar in detail to that described, except that the uncinate duct was isolated and dissected free from its surrounding parenchyma so as to protrude from the divided stump of the gland. A crushing ligature of fine surgical gut was tied tightly about the protruding duct. One end of the ligature was then passed as a suture through the exposed jejunal submucosa and tied firmly to the other end, thus bringing the crushed duct against the mucosa in a firm, necrotizing ligature (fig. 1 *D*). The pancreatic stump was secured into the jejunal wall in the usual manner (fig. 1 *C*).

All animals survived and remained in good condition. Each was fed the same diet of prepared commercial dog food containing relatively low concentrations of protein and fat. No particular effort was made to supply pancreatic secretagogues.

Observations of the state of the pancreaticoenterostomy were made at intervals varying from seven to forty-eight days by the following technic. The abdomen of each dog was reopened, with the animal under anesthesia induced by intravenous injections of pentobarbital sodium, and the pancreaticoenterostomy exposed. The

jejunum adjacent to the pancreatic attachment was opened widely, exposing that portion of the mucosal surface apposed to the transected uncinate process. A concentrated, highly active preparation of secretin,[11] varying in amount from 10 to 20 cc. according to the size of the animal, was then injected into the vena cava. In the instances in which a fistula had developed from the uncinate stump into the jejunum, pancreatic juice could be seen grossly dropping from the small ductular orifice in the mucosa within three to eight minutes of the injection. When fistula formation had not occurred, no response to the secretin was noted. The potency of the secretin was determined by opening the duodenum and observing simultaneously the increased flow of both bile and pancreatic juice from the ampulla of Vater.

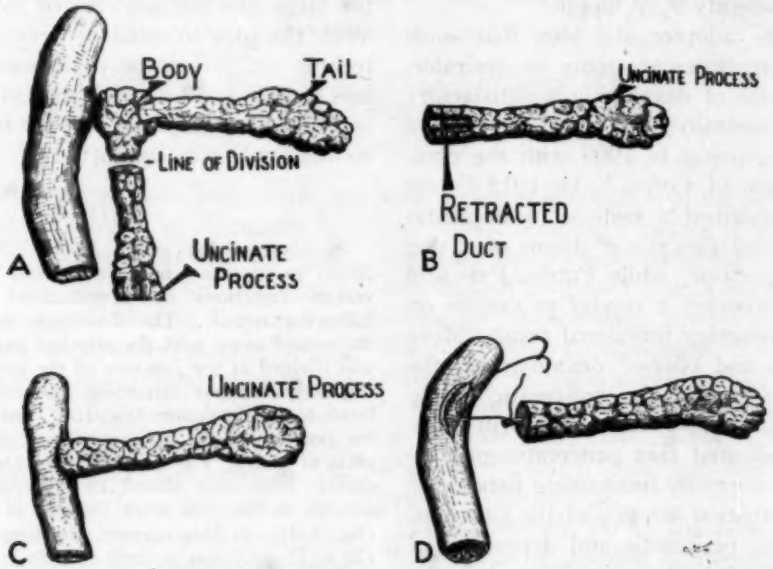

Fig. 1.—*A*, the line of division at the junction of the uncinate process and the body. *B*, the divided end of the uncinate duct retracted into the parenchyma of the gland. *C*, the stump of the divided uncinate process, with its retracted duct, implanted into the jejunal wall. *D*, the end of the ligature passed as a suture through the exposed jejunal submucosa.

A Comparison of Findings in Experiments Performed by Us and by Cattell

	Dog	Days Postoperatively	Gross Findings: Response to Secretin	Gross Findings: Pancreatic Stump	Microscopic Changes: Acute Pancreatitis	Microscopic Changes: Pancreatic Fibrosis	Microscopic Changes: Pancreaticojejunal Fistula
Our technic	1	23	Positive	Soft	None	Moderate patchy	Complete
	2	23	Positive	Soft	None	Slight patchy	Complete
	3	40	Positive	Soft	Moderate diffuse	Slight patchy	Complete
	4	9	Negative	Indurated	None	Moderate diffuse	Complete
	5	7	Negative	Indurated	None	None	Complete
	6	23	Positive	Indurated	Slight patchy	Slight patchy	Complete
	7	21	Negative	Indurated	None	Moderate diffuse	None
	8	36	Negative	Indurated	None	Moderate diffuse	None
	9	26	Negative	Large cyst	Large cyst	.....	None
	10	21	Positive	Soft	None	Slight patchy	Complete
	11	7	*	Soft	Slight patchy	Slight patchy	None
	14	30	Positive	Atrophic	None	Moderate diffuse	None
	17	31	Positive	Soft	None	Slight patchy	None
	20	35	Positive	Soft	None	None	Complete
	22	48	Positive	Atrophic	Moderate diffuse	Moderate diffuse	Complete
Modified technic of Cattell	12	7	Negative	Indurated	Pronounced diffuse	Early slight	None
	13	30	Positive	Atrophic	None	Pronounced diffuse	None
	15	29	Positive	Soft	None	Moderate patchy	Complete
	16	34	Positive	Soft	None	Moderate patchy	Complete
	18	33	Positive	Soft	None	Slight patchy	Complete
	19	33	Positive	Atrophic	None	Moderate diffuse	None
	21	34	Positive	Atrophic	Pronounced diffuse	Slight patchy	Complete

* Animal died of air embolism before response could be determined.

After the functional status of the pancreaticojejunal junction had been determined, the entire uncinate process and several inches of the attached jejunum were excised for microscopic study of the tissues, with particular reference to acute pancreatitis, pancreatic fibrosis and development of pancreaticojejunal fistulas.

11. Luckhardt, A. B.; Barlow, O. W., and Weaver, M.: Note on a Rapid Method of Preparing a Highly Active Pancreatic Secretin Solution, Am. J. Physiol. **76**:182, 1926. Ivy, A. C.; Kloster, G.; Lueth, H. C., and Drewyer, G. E.: On the Preparation of Cholecystokinin, ibid. **91**:336, 1929. Ivy, A. C.; Kloster, G.; Drewyer, G. E., and Lueth, H. C.: The Preparation of a Secretin Concentrate, ibid. **95**:35, 1930.

RESULTS

None of the animals showed gross evidence of active peritonitis or fat necrosis, although local adhesions about the pancreaticoenterostomy were pronounced in 4 (18 per cent) and moderate in 11 (50 per cent); in the remaining 7 (32 per cent), adhesions were slight or absent. Other significant observations are summarized in the table.

Response to Secretin.—Of the 22 animals studied, 15 showed definite secretion of pancreatic juice at the pancreaticojejunal junction after intravenous injection of secretin, an incidence of spontaneous fistula formation of 68 per cent. One (dog 11) died of air embolism immediately after the injection of secretin into the vena cava, so that no determination of the secretory response could be made. Elimination of this animal from the series would result in an incidence of 71 per cent of spontaneous fistula formation.

Among the 6 remaining failures, dogs 4, 5 and 12 were tested within nine days of the operation. Despite the negative response of dogs 4 and 5, microscopic sections showed that a junction had been made between the pancreatic duct and the jejunal mucosa, while dog 12 showed acute pancreatitis and no evidence of fistula. Two other negative responses occurred, in dogs 7 and 8, investigated at twenty-one and twenty-six days respectively. Microscopic sections in these animals revealed diffuse fibrosis of the pancreatic stump, failure of the duct to form a junction with the jejunal mucosa and pronounced dilatation of the duct system (fig. 2). In the last failure, dog 9, a large retention cyst of the implanted stump developed, containing fluid which gave a strongly positive reaction for amylase.

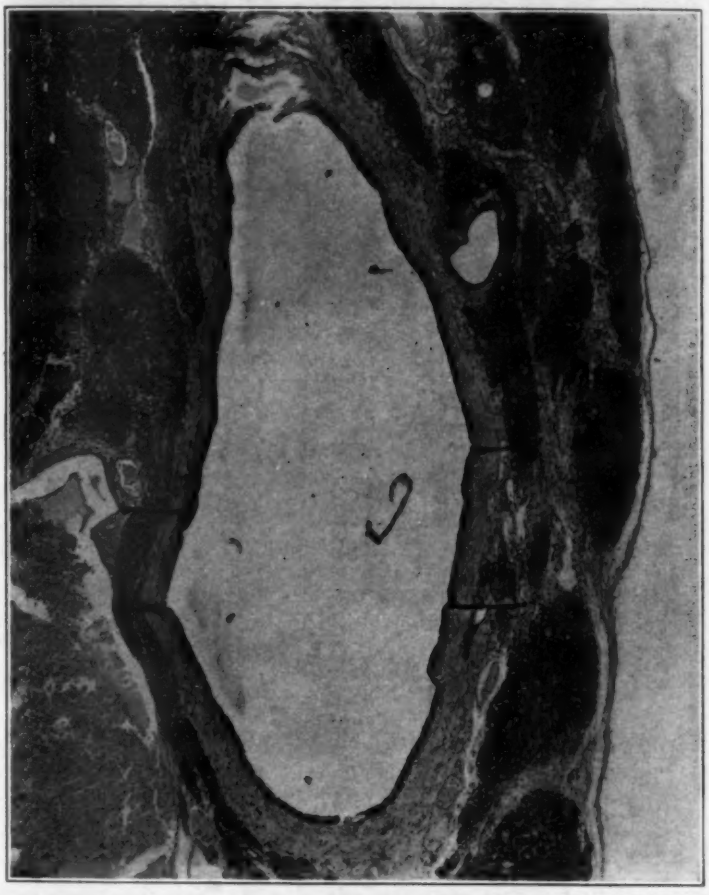

Fig. 2.—Pronounced dilatation of the duct due to obstruction from fibrosis. Note the flattened epithelial lining and the moderate degree of parenchymal scarring (× 40).

Acute Pancreatitis.—Microscopic studies of the implanted pancreatic stumps revealed some evidence of acute inflammatory reaction in 6 animals, an incidence of 27 per cent. As noted in the table, pronounced diffuse pancreatitis was

Pancreaticojejunal Fistula
Complete
Complete
Complete
Complete
Complete
Complete
None
None
None
Complete
None
None
None
Complete
Complete
None
None
Complete
Complete
Complete
None
Complete

found in only 2 instances, dogs 12 and 21. Each of these dogs appeared quite healthy, and neither showed any evidence of fat necrosis or peritonitis. Dog 12 was killed on the seventh postoperative day, and the following observations were made: negative response to secretin, induration and early fibrosis of the pancreatic stump and no microscopic evidence of fistula. Dog 21 was killed thirty-four days after operation. In spite of an extreme degree of acute pancreatitis, this animal responded satisfactorily to intravenous injections of secretin, although the flow of pancreatic juice was sluggish; other abnormal conditions observed included induration, atrophy and slight patchy fibrosis of the implanted stump and microscopic evidence of a junction between the duct and jejunal mucosa.

Of the other 4 animals, showing less severe degrees of acute pancreatitis, dogs 3, 6 and 22 revealed both positive response to secretin and microscopic evidence of fistula. The fourth, dog 11, died of air embolism before the secretory function could be determined; there was no microscopic evidence of fistula.

Pancreatic Fibrosis.—Fibrous tissue infiltration of the pancreatic stump was noted in the majority of animals, only 2 presenting no evidence of scarification. Of these, dog 5, killed on the seventh postoperative day, was found to have no acute pancreatitis and definite microscopic evidence of fistula formation, despite a negative response to secretin. The other animal showing no fibrosis of the pancreatic stump, dog 20, presented no acute pancreatitis, a grossly soft, normal stump, positive evidence of fistula development and a positive response to secretin (fig. 3).

Fig. 3.—Uncinate process thirty-five days postoperatively (dog 20). Note the absence of fibrosis, inflammatory reaction and dilatation of the duct (× 150).

Some degree of scar tissue formation was demonstrable in 20 animals (91 per cent). In only 1, dog 13, was the fibrosis considered pronounced when investigated thirty days after operation (figs. 4 and 5). This animal presented an indurated and atrophic stump, no acute pancreatitis and no microscopic evidence of fistula; despite these findings, the response to secretin was definitely positive, although the flow of pancreatic juice was sluggish. In the remaining 19 animals, fibrosis was considered moderate in 9 and slight in 9, while a large retention cyst

developed in 1 (dog 9; see preceding paragraphs). Response to secretin in the 18 animals showing moderate or slight infiltration of the fibrous tissue of the pancreatic stump was positive in 13 and negative in 4, while 1 died of air embolism before a definite impression of the secretory activity could be made (dog 11; see preceding paragraphs). Elimination of this animal and dog 9 (retention cyst) from the series would provide a total of 18 showing some degree of fibrosis, varying from slight to extreme; of these, 14 responded to secretin in a positive manner, while 4 failed, an incidence of successful fistula formation of 78 per cent. The failures included 2 dogs (4 and 12) investigated within nine and seven days, respectively, of the operation. In these, no microscopic correlation could be made between the fibrosis and the absence of pancreatic secretion. On the other hand, the 2 remaining failures (dogs 7 and 8) showed pronounced dilatation of the duct system due to the formation of scar tissue, which prevented spontaneous "breakthrough" of the main duct into the jejunum (fig. 2).

Pancreaticojejunal Fistula.—Definite microscopic evidence of a junction between the mucosa of the uncinate duct and the mucosa of the jejunum was detectable in 13 of the 22 animals studied, an incidence of 59 per cent. When this figure is compared with the figure for positive responses to secretin, 71 per cent, a pronounced discrepancy is immediately obvious. This can be explained largely by two factors. First, the uncinate duct of the dog is small, giving rise to considerable difficulty in passing the microtome through its long axis at the exact point of junction with the jejunum. Second, tortuosity of the duct increases the problem of a true longitudinal section, despite the fact that many attempts may be made on a single specimen. That a fistula may exist despite failure to demonstrate it microscopically can be proved, in addition to the secretin test, by a third method, which was employed sucessfully in dogs 17

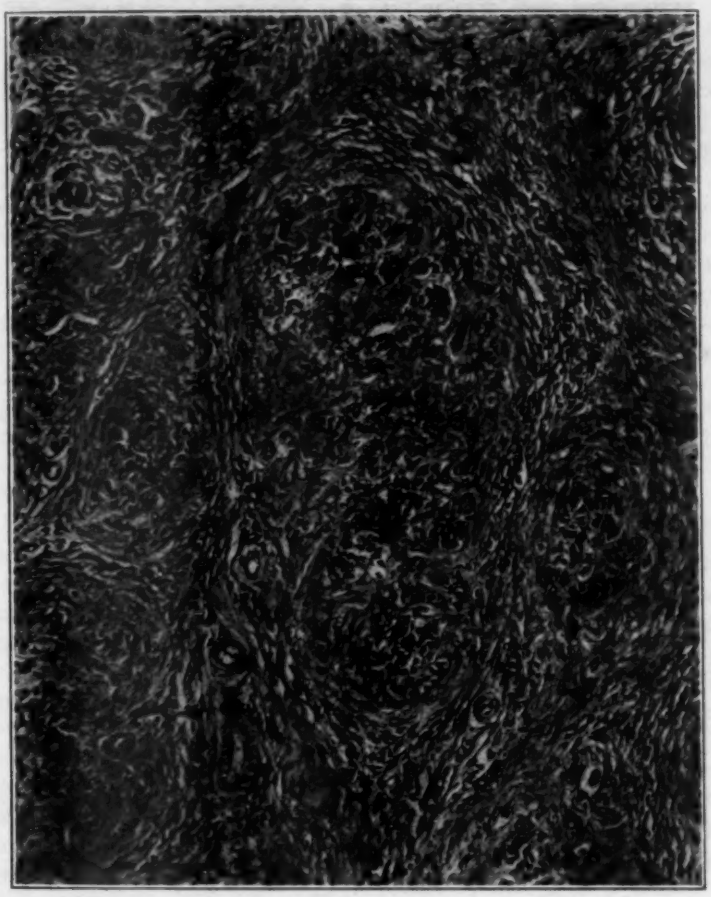

Fig. 4.—Extensive interlobular and intralobular fibrosis (dog 13) thirty days postoperatively. Positive response to secretin despite pronounced replacement of acini by scarring (× 150).

and 19. The small duct was dissected free from the pancreatic parenchyma in the distal portion of the uncinate process. Injection of water into the duct through a hypodermic needle resulted in appearance of the water in the jejunal lumen at the fistulous opening.

COMMENT

An evaluation of the results of this study should pertain primarily to the functional effectiveness of the pancreaticojejunostomy as regards the usual complications of radical pancreatic surgical treatment. The latter sequelae consist of external pancreatic fistula, acute pancreatitis, retention cyst and chemical peritonitis. The incidence of severe acute pancreatitis was 9 per cent in the animals studied, while only one retention cyst was found. There was no external pancreatic fistula and no peritonitis. On the basis of these results, it can be concluded that aseptic pancreaticojejunostomy in dogs according to the technic outlined is attended by a low incidence of the complications which commonly follow division of the pancreas.

This study was designed to develop not only an aseptic and time-saving method of disposal of the pancreatic stump but also a means of preserving the external secretion of the pancreas. Regarding the latter phase of the problem, results have been satisfactory, although some frank failures have occurred. Seven animals showed absence of secretory activity at the pancreaticoenterostomy after intravenous injection of secretin. One of these, dog 11, died of air embolism (see preceding section) and can be excluded from the series. Of the remaining 6, dogs 4, 5 and 12 were studied nine, seven and seven days, respectively, after operation. There was neither pancreatitis nor fibrosis of notable extent of the implanted stump in dogs 4 and 5, while each was found to have microscopic evidence of a junction between the duct epithelium and the jejunal mucosa. Inasmuch as there was demonstrated none of the factors which may interfere with secretion, the question arises as to how early secretory activity may begin after pancreaticoenterostomy. Dog 12, although apparently healthy, showed microscopic evidence

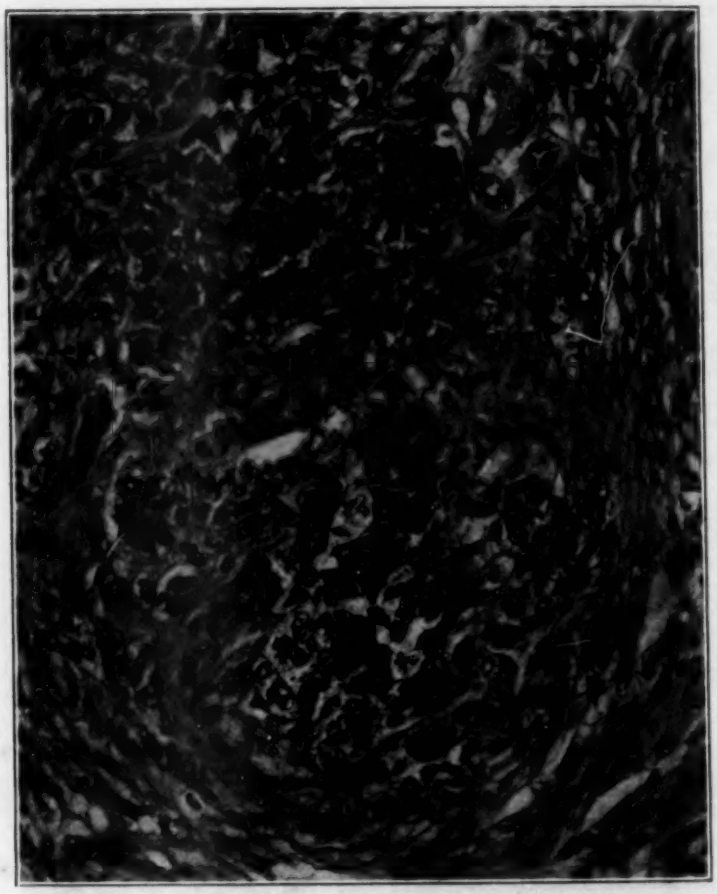

Fig. 5.—High power field of figure 4. Note the limited preservation of normal acinar elements.

of pronounced diffuse acute pancreatitis unaccompanied by fat necrosis. This factor, in association with the short postoperative interval, was considered sufficient explanation for failure of secretion to occur. The other failures were dogs 7, 8 and 9, all killed three weeks or more after operation. The first 2 showed moderate diffuse fibrosis with considerable dilatation of the duct (fig. 2), and no evidence of pancreatitis, indicating that obstruction of the duct resulted from fibrosis of the adjacent parenchyma. In dog 9 a large retention cyst developed which replaced the entire uncinate parenchyma, owing to failure of the duct to break through the jejunal wall. Studies of the excised specimens of dogs 7, 8 and 9 failed to reveal any explanation of the selective action of fibrous tissue in causing obstruction of the ducts. Furthermore, it could not be determined from the investigations what factors decided whether cyst formation or simple dilatation would occur.

Varying degrees of acute pancreatitis occurred in 6 animals. Two of these showed evidence of slight patchy inflammation, principally around the sutures; 2, moderate diffuse reactions which did not interfere with secretion and 2, extreme diffuse inflammatory infiltration. In those animals in which the uncinate duct was allowed to retract into the parenchyma of the gland, a collection of pancreatic juice might be expected to develop at the site of implantation, pending spontaneous breakthrough into the jejunum, in a high percentage of instances. In such circumstances, diffuse pancreatic necrosis would be inevitable in a considerable number of cases. The development of slight, patchy, acute pancreatitis in 2 dogs and moderate diffuse pancreatitis in 2 is evidence that such a situation does not occur frequently. On the other hand, a crushing ligature about the duct, holding it firmly against the jejunal submucosa, should minimize the local accumulation of pancreatic secretion and thereby eliminate the subsequent development of diffuse pancreatitis. Actually, the only 2 instances of severe pancreatitis occurred in animals subjected to the latter technic. The first was found in dog 12, investigated seven days after operation and showing a negative response to secretin. The second was found in dog 21, thirty-four days postoperatively, in which the reaction to secretin was positive. In the latter animal, the pancreatitis was acute and the fibrosis was minimal, indicating that the inflammatory process developed late in the postoperative course. The interesting aspects of this case pertain to the pathogenesis of the pancreatitis and to the possibilities of its late effects had the animal been allowed to live longer. At the time the dog was killed, there was no obvious condition to suggest a disease of any kind.

Despite the fact that 15 dogs presented no evidence of acute pancreatitis, some degree of fibrosis was noted in all but 2 of the total number. This situation may be interpreted as meaning that at some period of the postoperative course inflammatory infiltration of the implanted stump occurred, being displaced by scar tissue at a later date. If this reasoning is correct, it is suggested that acute pancreatitis develops shortly after operation in the majority of animals, is limited in its scope and is successfully replaced by fibrous tissue proliferation. An important observation is the fact that of 18 animals showing varying degrees of fibrosis of the stump (omitting dogs 5, 9, 11 and 20; see the table), only 4 showed a negative response to secretin. It is significant that considerable amounts of acinar tissue can be replaced by scar without eliminating the secretory function of the gland (fig. 4). Apparently, as noted in dogs 7, 8 and 9 (see the preceding section), scarification interferes with function only when it causes obstruction of the duct. There are no possible means of predicting this selective action before pancreaticojejunostomy is performed, but its incidence is low in the animals studied in this series.

SUMMARY AND CONCLUSIONS

An aseptic technic of implanting the transected uncinate process of the dog's pancreas into the wall of the jejunum is described.

Spontaneous fistula formation developed between the divided pancreatic stump and the jejunum in 71 per cent of the animals, as determined by the appearance of pancreatic juice at the fistula after intravenous injection of secretin.

A low incidence of the usual complications of transection of the pancreas occurred, there being no peritonitis, no external pancreatic fistula, 1 retention cyst and 2 instances of severe acute pancreatitis.

All animals survived and remained in good health regardless of whether complicating factors developed or whether pancreaticojejunal fistulas were formed.

A significant fact noted was that fibrous tissue infiltration of the implanted pancreatic stump can occur to a considerable extent without interfering with the secretory function of the gland.

Results obtained in this study suggest application of the methods described to patients undergoing radical surgical treatment of carcinoma involving the head of the pancreas and the periampullary region, for whom preservation of the external secretion of the pancreas is desired.

INTUSSUSCEPTION OF THE VERMIFORM APPENDIX

REPORT OF A CASE

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Intussusception of the appendix into itself is rare, and only 2 cases have previously been reported. The purpose of this paper is to report another case and to discuss the pathologic picture and possible etiologic factors of this condition.

Frazer (1943)[1] stated that at the time of his report there had been about 100 cases of appendical intussusception of all types recorded in the literature. He added 7 more and reviewed 75 out of the 100 previously reported. This group included all three types of intussusception: (*a*) simple, i. e., into itself; (*b*) the appendix invaginating into the cecum, either partial or complete, and (*c*) compound, i. e., the appendix invaginating into the cecum and the cecum into the ascending colon. This paper deals with the simple type of intussusception and adds a third case of this kind.

F. Whitrow (1930)[2] presented the first case report. Her patient was a 12 year old boy who was admitted to the hospital with a history typical of acute appendicitis of eighteen hours' duration. At operation the appendix was found to be the site of intussusception, the tip having invaginated itself until it lay at the base of the appendix. An appendectomy was performed, and the patient's recovery was uneventful.

The second case was reported by Frazer in 1943. His patient was a 75 year old woman who had both intussusception of the appendix and carcinoma of the cecum. In this instance, the appendical intussusception was at the base of the appendix, where the walls were telescoped on themselves for ½ inch (1.3 cm.). The patient's symptoms were referable to the cancer of the large bowel, and the intussusception was observed incidentally.

All other cases of appendical intussusception which have been reported are of the compound type. The earliest case was described in the *Edinburgh Medical Journal* in 1859 by McKidd.[3] The patient was a 7 year old boy who had severe abdominal pain for two months prior to death. At autopsy the appendix was found to be intussuscepted into the cecum, which, in turn, was intussuscepted into the ascending colon. McGraw[4] in 1897 reported the first successful operative case. He found an intussusception of the compound variety and was able to resect the invaginated cecum and appendix without difficulty.

The causation of appendical intussusception has been explained as follows: The appendix is capable of rhythmic peristaltic contraction; these contractions on encountering an area of inflammation within the wall of the appendix or an adherent concretion result in a buckling inward of the mucosa followed by the muscularis and serosa, with the development of an intussusception. If the base of the appendix is constricted and a foreign body or fecalith becomes impacted, the forceful peristaltic action of the appendix may carry that organ into the cecum. Previous inflammatory processes, such as acute appendicitis, may therefore set the stage for intussusception. Intussusception of the tip of the appendix is more difficult to explain because the leading point is small. There should be some nodule at the tip in these rare cases to serve as the starting point. In our case there was definite microscopic endometriosis in the ovaries, and clinically it was present in the gross specimen of the appendix. Owing to the loss of the appendix before it was sectioned, the endometriosis in that organ was not proved.

The history given by a patient with appendical intussusception is usually that of crampy pain in the center of the abdomen, with tenderness in the right iliac fossa. Colic is characteristic and is severe; vomiting may occur, and some patients pass blood by rectum. On physical examination the patient has signs of inflammation in the right lower abdominal quadrant, and occasionally a mass is palpable above McBurney's point. In the more complicated cases, a barium sulfate enema has in some instances demonstrated the intussusception of the cecum

1. Frazer, K.: Brit. J. Surg. **31**:23, 1943.
2. Whitrow, F.: Brit. M. J. **2**:181, 1930.
3. McKidd, J.: Edinburgh M. J. **4**:793, 1859.
4. McGraw, T. A.: Brit. M. J. **2**:956, 1897.

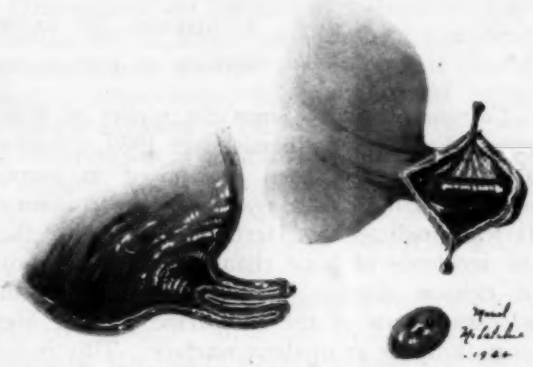
into the ascending colon. If the intussusception becomes compound, then the clinical picture is that of intestinal obstruction.

The treatment of intussusception of the appendix into itself is appendectomy. In the event of a completely intussuscepted appendix, the appendix is removed by resecting a small cuff of cecum which surrounds the base of the appendix. The compound variety may be easily reduced, but if gangrenous, resection of a portion of the cecum and anastomosis of the ileum to the ascending or transverse colon are required.

REPORT OF A CASE

A 45 year old bipara was seen by a physician three years prior to operation for severe pain of twelve hours' duration in the right lower quadrant. The sudden acute pain was associated with nausea, vomiting and abdominal tenderness. Physical examination demonstrated tenderness without spasm in the right lower quadrant, a normal uterus and normal vaults. Her white blood cell count was 22,500, blood pressure 96 systolic and 60 diastolic and pulse rate 64. The urine was normal. Her pain and tenderness subsided in forty-eight hours, and she was well until one month later, when a similar pain in the right lower quadrant of the abdomen occurred. During the next six months she was free of pain, and physical examination revealed no abnormalities on three occasions. Two years later the pain recurred, associated with a slight fever. Still later the patient was referred to us. We found nothing abnormal on abdominal examination but an enlarged uterus. There was a large cystic mass in the right vault. On Nov. 24, 1943, with the patient under nitrous oxide, oxygen and ether anesthesia, an appendectomy, total hysterectomy and bilateral salpingo-oophorectomy were performed. The appendix was short and broad, and the junction of the appendix and cecum was unusually wide, measuring 1.5 cm. Because of its wide base, the appendix was removed between two Kocher clamps and the stump closed with two rows of chromic surgical gut stitches. Both ovaries were destroyed by large endometriomas which were adherent to a uterus containing fibroids and also to the under surfaces of the broad ligaments. The patient made an uneventful recovery.

The Specimen.—The distal half of the appendix had intussuscepted into the proximal half, and the invaginated mucosal surface of the tip of the appendix was smooth and glistening and was not ulcerated. The inverted end filled the wide lumen of the appendix, and the tip lay almost at the junction of the appendix and the cecum. In the accompanying drawing the wide base of the appendix is illustrated, as is the relationship between



Showing the wide base of the appendix and the relationship between appendix and cecum. At lower right the slight dimple at the end of the appendix is shown.

the cecum and the appendix. An end on view of the appendix is shown to demonstrate the slight dimple present, and on either side of the dimple there were bluish spots which were undoubtedly small endometriomas. Because of the loss of the appendix before microscopic examination, the diagnosis of endometriosis cannot be substantiated.

The first attack of pain, three years before operation, was undoubtedly acute appendicitis. This inflammatory process may well account for the subsequent development of the intussusception. The recurrence of the pain which necessitated further examination and operation in all probability was due to the intussusception, although the large endometriomas may have played some part in the production of the abdominal pain.

PROGRESS IN ORTHOPEDIC SURGERY FOR 1944

A REVIEW PREPARED BY AN EDITORIAL BOARD OF THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

I. DISEASES OF GROWING AND OF ADULT BONE

PREPARED BY JOHN A. SIEGLING, M.D., CHARLESTON, S. C.*

Caisson Disease.—Since the report of Kahlstrom, Burton and Phemister in 1939, considerable interest has been manifested in aseptic necrosis of bone as a result of caisson disease. It was predicted by Hertzmark[1] in 1942 that the incidence of bone changes similar to those in caisson disease would increase with the widespread use of the submarine and the high altitude flying in modern warfare. This is not borne out, however, for a review of the past year's literature reveals a dearth of material on the subject. Taylor,[2] in two articles covering essentially the same material, presents observations in 12 cases of occupational exposure and 38 of patients who had never worked under compressed air. The articles are interesting in that he reports cases of aseptic necrosis roentgenologically identical with osseous lesions of caisson disease in persons not exposed to increased atmospheric compression. No theory as to the causation of the lesion in persons not working in caissons is advanced.

Osteitis Deformans.—Reifenstein and Albright[3] give an excellent presentation of a new concept of osteitis deformans (Paget's disease). Normal bone metabolism, metabolic abnormalities in osteoporosis as opposed to those in osteomalacia and osteitis fibrosa generalisata and the morbid anatomy of Paget's disease are reviewed with clarity. Two case reports are presented, in which it is made clear that immobilization of fractures leads to a pronounced increase in urinary calcium and even hypercalcemia, which may be sufficient to bring about chemical death. Warning signs of hypercalcemia are listed as nausea and emesis. A hitherto undescribed sign, to which attention is called, is a sensation of dryness in the throat with dysphagia. In cases in which hypercalcemia and hypercalcinuria develop, the authors make it clear that treatment is simple and consists of low calcium diet and fluids given intravenously to keep the serum and urinary calcium levels low. A minimum of immobilization is advisable. The authors' interpretation of the pathologic physiology of Paget's disease is as follows and is rational: The initial lesion is destructive and has no respect for structural requirements. Destruction renders the involved bone more susceptible to stresses and strains. As a compensatory factor, the osteoblasts are stimulated to lay down more matrix; the serum phosphatase level therefore rises. In bones in which stresses and strains are always present, repair occurs concomitantly with destruction; in bones in which stresses and strains are minimal, as in the skull, repair may lag behind destruction. The joints between new and old bone are marked by cement lines, of which there are many, and, since the local destructive factor has no respect for the mechanical requirements of the skeleton, the lines have no order and therefore are mosaic in character. A bone of poor architectural value results, explaining three of the striking clinical characteristics of the disease: the pronounced tendency to overgrowth of bone, the high level of serum phosphatase per unit of diseased bone and the tendency toward deformity in spite of definite overgrowth. This concept of the disease is applicable to the striking case report of Wycis.[4] Softening of architecturally weak bone has been reported as causing compression of the cord, but his is the first case of platybasia due to Paget's disease in which molding of the bone of the base of the skull caused

1. Hertzmark, M. H.: Bone Changes in Caisson Disease: Report of a Case, Bull. Hosp. Joint Dis. **3**: 128-133 (Oct.) 1942.

2. Taylor, H. K.: Aseptic Necrosis and Bone Infarcts in Caisson and Non-Caisson Workers, New York State J. Med. **43**:2390-2398 (Dec. 15) 1943; Aseptic Necrosis in Adults: Caisson Workers and Others, Radiology **42**:550-569 (June) 1944.

3. Reifenstein, E. C., Jr., and Albright, F.: Paget's Disease: Its Pathologic Physiology and the Importance of This in the Complications Arising from Fracture and Immobilization, New England J. Med. **231**:343-355 (Sept. 7) 1944.

4. Wycis, H. T.: Basilar Impression (Platybasia): A Case Secondary to Advanced Paget's Disease with Severe Neurologic Manifestations; Successful Surgical Result, J. Neurosurg. **1**:299-305 (Sept.) 1944.

encroachment on the brain, resulting in severe neurologic symptoms. An unusually good result followed surgical treatment in which laminectomy and suboccipital decompression were done.

Neurofibromatosis and Osteitis Fibrosa Cystica.—In an excellent article Thannhauser [5] manifests interest in these conditions. Information continues to be added to the knowledge of them, though in their essential clinical features they are much the same as von Recklinghausen described them. Even he referred to cases with identical features reported by previous authors. The French school, led by P. Marie and H. Bernard, added to the syndrome the pigmentary anomalies of the skin, while the German, English and American literature added the visceral and the osseous changes. Mandl contributed a great advancement in knowledge when he described extirpation of an adenomatous parathyroid gland from a patient suffering from osteitis fibrosa cystica. Knowledge was also added by the physiologic studies of Collip.

Thannhauser clarifies the pathogenesis of osteitis fibrosa cystica localisata and disseminata (von Recklinghausen) and demonstrates that under the heading of osteitis fibrosa cystica Recklinghausen two etiologically different entities are reported: Osteitis fibrosa cystica disseminata is shown to be related by its clinical and histologic features to neurofibromatosis (Recklinghausen); hyperparathyroidism with resulting fibrocystic lesions of bone is primarily caused by hyperfunction or adenoma of one or both parathyroids.

Coburn [6] emphasizes that in cases of parathyroid adenoma the diagnosis is often overlooked and states that this is regrettable because of the brilliant results from early extirpation. He reports a case in detail in which symptoms were manifest over a period of fifteen years.

Ordinarily, after removal of a parathyroid adenoma, the skeleton lesions recalcify. Voltz and Smull [7] report a case, however, in which in five postoperative years this failed to occur, though there was no recurrence of hyperparathyroidism.

Alexander, Pemberton, Kepler and Broders [8] summarize completely most of the knowledge of parathyroid tumors to date. They report 14 cases and lay stress on the widely divergent clinical pictures. It is brought out that the changes in bone appear to be an index more of duration than of severity.

Osteomalacia.—Ghormley and Hinchey [9] suggest the use of aluminum acetate in treatment of malacic bone diseases. They present clinical cases of improvement in symptoms and roentgenologic evidence of increase in calcification as justification for its clinical trial and as a stimulus to research. A high percentage of improvement was noted in cases of osteoporosis, osteitis deformans, osteitis fibrosa and osteogenesis imperfecta.

The incidence of renal lithiasis in this series was 60 per cent. In 13, or 92.8 per cent, of the cases, the tumor showed cytologic evidence of malignancy. The malignant nature of the tumors makes complete removal imperative, according to the authors. It is therefore not advisable to leave tissue to avoid tetany, as this condition can be controlled with calcium and vitamin D.

Fibrous Dysplasia of Bones (Albright Syndrome).—Dockerty, Meyerding and Wallace [10] report the thirty-fourth case in the literature since the description of fibrous dysplasia of bones in 1937 by Albright. In the case presented there was the characteristic triad of rather dissociated manifestations, consisting in disseminated fibrosis of bone, patchy cutaneous pigmentation and precocious puberty in females.

Osteogenesis Imperfecta.—For some time, discussion has centered around the question as to whether osteogenesis imperfecta (Vrolik), in which there are intrauterine fractures, differs from the Lobstein type, in which only postnatal fractures occur. Rosenbaum [11] reports cases of the two types in the same family, tending to disprove the duality of the syndromes as propounded by Glanzmann. In addition, he found

5. Thannhauser, S. J.: Neurofibromatosis (von Recklinghausen) and Osteitis Fibrosa Cystica Localisata et Disseminata (von Recklinghausen), Medicine **23**:105-149 (May) 1944.

6. Coburn, D. E.: Severe Osteitis Fibrosa Cystica with Parathyroid Tumor, Am. J. Surg. **66**:252-258 (Nov.) 1944.

7. Voltz, C. P., and Smull, K.: Hyperparathyroidism with Failure to Recalcify After Removal of Parathyroid Adenoma (A Case Report), Ann. Int. Med. **21**:329-332 (Aug.) 1944.

8. Alexander, H. B.; Pemberton, J. deJ.; Kepler, E. J., and Broders, A. C.: Functional Parathyroid Tumors and Hyperparathyroidism, Am. J. Surg. **65**: 157-188 (Aug.) 1944.

9. Ghormley, R. K., and Hinchey, J. J.: The Use of Aluminum Acetate in the Treatment of Malacic Diseases of Bone, J. Bone & Joint Surg. **26**:811-817 (Oct.) 1944.

10. Dockerty, M. D.; Meyerding, H. W., and Wallace, G. T.: Albright Syndrome (Fibrous Dysplasia of Bones, with Cutaneous Pigmentation in Both Sexes and Gonadal Dysfunction in Females), Proc. Staff Meet., Mayo Clin. **19**:81-88 (Feb. 23) 1944.

11. Rosenbaum, S.: Osteogenesis Imperfecta and Osteopsathyrosis, J. Pediat. **25**:161-167 (Aug.) 1944.

on laboratory analysis that the values for serum calcium and inorganic phosphorus fluctuate in the course of the disease and fail to form a basis of distinction between the two types. The author postulates a common pathogenesis, implicating the hypophysis and advises treatment with anterior pituitary extract, as it has given good results in his cases.

Leprosy and Yaws.—Several interesting reports on these rather unusual diseases have been made. Cooney and Crosby[12] state that in leprosy absorption of bone, particularly in the phalanges, is frequently observed. Case reports and roentgenograms are presented, and the authors state that all the factors for absorption of bone are present, namely, disturbances of circulation, anesthesia and pressure. They believe that these factors working together without any other lytic agent are sufficient to cause the absorption and disappearance of bones.

Faget and Mayoral,[13] in reviewing 505 cases of leprosy, found that osseous changes are found preponderantly in the neural type and are neurotrophic in nature. They are not characteristic but are similar to and essentially indistinguishable from other neurotrophic conditions. Osseous lesions in lepromatous leprosy are rare. These changes are due to involvement of the bone marrow or periosteum by the Hansen baccilli or to a vascular leprosy of the supplying arteries, in contradistinction to the neural type, which is purely neurotrophic and not due to the bacillus.

Helfet[14] reports that yaws is the most common disease of bone in the tropics. While textbooks liken it to syphilis and most descriptions are of the chronic lesions, the author feels that yaws is more acute. The Wassermann test, however, invariably elicits a positive reaction, and the clinical response to arsenicals is dramatic.

Growth and Regeneration of Bone.—Bourne[15] states that many workers have attempted to show experimentally, or simply by speculation, that one or another of the various bone elements has to do with regeneration. The most important role has been variously ascribed to osteocytes (Cohn and Mann); connective tissue of callus (Leriche and Policard); osteoblasts (Keith, Girdlestone and Harris); periosteum (Hertz), and latterly, endosteum and periosteum (Urist and McLean). The author, because of the difficulty of obtaining identical fractures, has studied regeneration in bones (femoral and cranial) in guinea pigs and rats. His work corroborates the belief that endosteum and periosteum play an important part in regeneration. He also concludes that regeneration of bone is impaired by a deficiency of ascorbic acid.

Finkler, Furst and Klein[16] report studies of 81 children treated with endocrine substances: 18 with thyroid; 26 with anterior pituitary extract; 19 with chorionic gonadotropin, and 18 with testosterone propionate. They conclude that thyroid therapy tended to improve density of bone and epiphysial union. Therapy with anterior pituitary extract failed to yield conclusive changes in skeletal and growth development. Chorionic gonadotropin stimulated growth of bone in the longitudinal axis but did not accelerate epiphysial union or density of bone. Testosterone showed a tendency to accelerate skeletal growth to a greater degree than chorionic gonadotropin. No hastening of epiphysial union was observed. A moderate degree of increased density of bone was noted, however, in 3 of 18 children.

Reynolds[17] attempts to determine whether there is a greater similarity in the pattern of appearance of certain ossification centers in related than in unrelated children. Twins, siblings, first cousins and unrelated children were used in the study. The conclusion was that patterns are more similar the more closely the children are related. Heredity is implicated as the probable reason.

In a study of seasonal differences in weight, height and appearance of ossification centers in 133 children during the age span from 12 to 60 months, Reynolds and Sontag[18] conclude that seasonal variations, similar in the two sexes, occur as follows: in weight, pronounced; in ossification, moderate, and in height, slight. The authors feel that analyses of deviations in individual growth curves should take into consideration the season of the year which is covered by the interval between measurements.

12. Cooney, J. P., and Crosby, E. H.: Absorptive Bone Changes in Leprosy, Radiology **42**:14-19 (Jan.) 1944.

13. Faget, G. H., and Mayoral, A.: Bone Changes in Leprosy: A Clinical and Roentgenologic Study of 505 Cases, Radiology **42**:1-13 (Jan.) 1944.

14. Helfet, A. J.: Acute Manifestations of Yaws of Bone and Joint, J. Bone & Joint Surg. **26**:672-681 (Oct.) 1944.

15. Bourne, G. H.: The Relative Importance of Periosteum and Endosteum in Bone Healing and the Relationship of Vitamin C to Their Activities, Proc. Roy. Soc. Med. **37**:275-279 (April) 1944.

16. Finkler, R. S.; Furst, N. J., and Klein, M.: Clinical and Roentgenologic Study of Effects of Hormone Therapy on Bone Growth, Radiology **43**:346-357 (Oct.) 1944.

17. Reynolds, E. L.: Degree of Kinship and Pattern of Ossification, Am. J. Phys. Anthropol. **1**:405-416 (Dec.) 1943.

18. Reynolds, E. L., and Sontag, L. W.: Seasonal Variations in Weight, Height and Appearance of Ossification Centers, J. Pediat. **24**:524-535 (May) 1944.

Holm [19] calls attention to the lines formed in growing bones as a result of phosphorus poisoning and shows by roentgenograms that they may last a lifetime.

Ligaments, Muscles and Tendons.—Kuhns [20] points out that ligamentous weakness is present and easily discernible as a clinical entity in 10 per cent of children but that ligamentous tightness is also present in many and has received scant attention. Tightness is found more frequently in the hamstring and back areas.

Goldberg and Comstock [21] emphasize the differential diagnosis of herniations of muscle observed in the legs from lipoma, hematoma, tuberculosis, pseudo hernia and varices. A case of multiple small hernias of the tibialis anterior muscles of both legs is presented.

In an analysis of 190 cases of chronic nonspecific tenosynovitis and peritendinitis, Lipscomb [22] feels that trauma is in most instances the etiologic factor. The pathologic changes are reviewed, and his opinion is that they differ only in degree and depend on the duration of the disease primarily. Conservative treatment consisting in splinting and roentgen ray therapy is advised, and if improvement does not occur surgical intervention is indicated.

19. Holm, O. F.: Beitrag zur Kenntnis der Entstehung der Phosphorsklerose, Acta radiol. **23**:549-561, 1942.

20. Kuhns, J. G.: Tightness of Ligamentous Structures, Arch. Pediat. **61**:179-183 (April) 1944.

21. Goldberg, H. C., and Comstock, G. W.: Herniation of Muscles of the Legs, War Med. **5**:365-367 (June) 1944.

22. Lipscomb, P. R.: Chronic Nonspecific Tenosynovitis and Peritendinitis, S. Clin. North America **24**: 780-797 (Aug.) 1944.

Osteochondritis.—Uhry [23] presents an interesting review of 79 cases of osteochondrosis of the tuberosity of the tibia (Osgood-Schlatter's disease) and defends the original ideas of the persons first describing the condition in which the disorder develops as a result of minor separation of the structures of the tibial tubercle and the patellar ligament. The author believes that the characteristic pathologic changes represent callus repair at the site of separation. He feels that osteochondritis as such (that is, inflammation) is not in evidence. The immediate instigating factor is consistently trauma.

Sudeck's Atrophy.—Buchman [24] reports an interesting case of Sudeck's atrophy following a single minor surgical procedure for exploration of a tendon sheath. The surgical treatment was followed by severe symptoms, partially relieved by injection of procaine hydrochloride after lack of response to usual methods of treatment.

Abuse of Bed Rest.—Since this article will probably not come within the purview of the editors of other sections of "Progress in Orthopedic Surgery," it is felt that it should be mentioned here. Ghormley [25] sounds a keynote of change from the emphasis placed on rest by Hugh Owen Thomas and cites the many disadvantages of rest as compared with early activity in the orthopedic field.

23. Uhry, E., Jr.: Osgood-Schlatter Disease, Arch. Surg. **48**:406-414 (May) 1944.

24. Buchman, J.: Postoperative Post-Traumatic Osteoporosis or Sudeck's Atrophy, Bull. Hosp. Joint Dis. **4**:55-61 (Oct.) 1943.

25. Ghormley, R. K.: Abuse of Rest in Bed in Orthopedic Surgery, J. A. M. A. **125**:1085-1087 (Aug. 19) 1944.

II. CONGENITAL DEFORMITIES

PREPARED BY J. HIRAM KITE, M.D., ATLANTA, GA.

For several years I have begun this section on "congenital deformities" with a description of the experiments conducted by Josef Warkany. Each year he and his workers have given additional information on the cause of some of the congenital deformities. This past year has brought information on how to prevent deformities.

In times past, various authors have attributed congenital malformations to a maternal nutritional deficiency. Warkany and Schraffenberger,[26] after establishing a set pattern of deformities which follow what they call diet I, made various additions to the diet, trying to prevent deformities. They found first that 2 per cent pig liver would prevent deformities. A search was made for the preventive factor in pig liver. After studying hundreds of litters of rats, they give the following conclusions:

The congenital malformations of the pattern of diet I are prevented when the maternal diet I is supplemented by riboflavin. Supplements of thiamine hydrochloride, nicotinic acid, pyridoxine and calcium pantothenate are not preventive. With a purified maternal diet in which the vitamin B complex is represented by crystalline substances, malformations of the pattern of diet I appear in the offspring when riboflavin is omitted. On the same diet supplemented by

26. Warkany, J., and Schraffenberger, E.: Congenital Malformations Induced in Rats by Maternal Nutritional Deficiency, J. Nutrition **27**:477 (June) 1944.

sufficient riboflavin, no deformed offspring are observed. It is concluded that a deficiency of riboflavin in the maternal diet is responsible for the congenital malformations of the pattern of diet I.

The late Beveridge H. Moore [27] gave further insight into congenital deformities by his study of peripheral nerve changes. He found that one or the other of the parents of a child showing the congenital malformation will frequently show definite stigmas of neurofibromatosis, even though the child himself does not. The pigmentation may not be seen in the child, but it makes its appearance later. He found in 2 cases of amputation for hypertrophy that there were nodules along the peripheral nerves. Some of the nodules showed changes typical of neurofibroma, while others showed a variety of changes. He studied the nerve between the nodules, where it was supposed to be normal, and found many secondary changes, a fact which he thinks is extremely important. The basic change is an increase in the fibrous tissue of the endoneurium. He calls these changes fibrotic degeneration. It is believed that they are either an early stage in the formation of a neurofibromatous nodule or an indication of its presence elsewhere in the nerve trunk. He studied all nerves available, those of spastic patients when the nerve was sectioned and those in supernumerary digits and in other deformities requiring amputation. He found that a surprisingly high proportion of this supposedly normal material showed changes corresponding to the secondary pathologic changes which have been referred to as fibrotic degeneration. The striking feature of the study was the high percentage of cases of pathologic changes in nerves and their relationship to the cutaneous pigmentation considered typical of pathologic changes of nerves. In a high percentage of congenital deformities varying degrees of pathologic changes in the peripheral nerves are shown. This observation seems to favor the neurogenic theory of the origin of congenital deformities.

Sections of peripheral nerves from 78 cases of various congenital deformities were studied with regard to disease. Of the 78 cases, 70, or 91 per cent, showed pathologic changes in the nerves.

[Ed. Note (L. D. B.).—Beveridge Moore, a fine gentleman, in his studies of peripheral nerve lesions made a major contribution to orthopedic surgery.]

27. Moore, B. H.: Peripheral Nerve Changes Associated with Congenital Deformities, J. Bone & Joint Surg. **26**:282 (April) 1944.

Two cases of multiple congenital deformities are reported by Hobbs.[28] These are used as the basis for a discussion of the hereditary factors in multiple congenital deformities. The literature is reviewed. The experiments causing inheritable deformity in animals through injury to the gonads by roentgen rays have given rise to the supposition among students of genetics that the clinical use of roentgen rays may be responsible for congenital deformities occurring in human progeny. Such disorders cannot be entirely charged to roentgen ray injury, nor is such injury believed to be a principal etiologic factor, since the deformities were commonly seen prior to the era of clinical radiology. The primary cause of clinical as well as experimentally produced hereditary deformities can be radiant energy or another agent capable of producing sublethal changes in the primary germ cell.

Swan and others [29] report further observations on congenital defects in infants following infectious diseases during pregnancy, with special reference to rubella. Recent work reported previously showed that maternal rubella in the early months of pregnancy may be followed by congenital defects (cataract, heart disease, deaf-mutism, microcephaly and glomerular sclerosis) in the infants born subsequently. The possibility that other infectious diseases in pregnancy may result in congenital abnormalities has been considered.

In the course of the present investigation, 13 infants were examined; 11 were found to have congenital abnormalities. In 12 instances the mothers had suffered from rubella during pregnancy; 10 of the infants born subsequently exhibited congenital defects. The abnormalities included cataract, deaf-mutism, heart disease, microcephaly and obliteration of the bile ducts. With three exceptions, all 10 mothers with congenitally defective children had contracted rubella within the first three months of pregnancy.

[Ed. Note (L. D. B.).—This association of congenital deformities with rubella during pregnancy adds further to the interest in the work of Cohn on the study of blood fractions, in that the gamma globulin has been shown to prevent rubeola. Additional studies are indicated to determine its effect on rubella.]

A case of epiphysial dysgenesis associated with cretinism in a premature infant is reported by

28. Hobbs, A. A.: Hereditary Factors in Multiple Congenital Deformities, Am. J. Roentgenol. **51**:677 (June) 1944.

29. Swan, C.; Tostevin, A. L.; Mayo, H., and Black, G. H. B.: Further Observations on Congenital Defects in Infants Following Infectious Diseases During Pregnancy, with Special Reference to Rubella, M. J. Australia **1**:409 (May 6) 1944.

Blatt, Zeldes and Goodfriend.[30] They pointed out that in 1927 Fairbank described "stippled epiphyses" associated with dwarfism, but he failed to recognize thyroid deficiency as the basis of the disturbance. Ten years later Reilly and Smythe described 5 similar cases, designating the condition as "cretinoid epiphysial dysgenesis." McCullough and Sutherland in 1940 described stippled epiphyses in a dwarf in whom there was no sign of hypothyroidism and used the term "epiphysial dysplasia puncticularis" to designate the skeletal change. Wilkins, who found bilateral epiphysial dysgenesis in 23 of 25 children with hypothyroidism, said that he had never seen true dysgenesis in any type of dwarfism other than that occurring with hypothyroidism.

In roentgenograms epiphysial dysgenesis is diagnosed by the appearance of multiple small irregular islets of calcification, scattered over a considerable area. The islets are irregularly spaced, and the anatomic distribution does not conform to that of the normal centers of ossification. As the islets grow larger or as new ones occur, they appear to coalesce and give the impression of a single large center which has undergone fragmentation. The defect is apparently due to an abnormality of endochondral ossification.

Roentgenologically, epiphysial dysgenesis may be confused with osteochondritis deformans. However, the latter usually occurs in epiphyses which previously have appeared normal on roentgen examination. Furthermore, osteochondritis deformans (Legg-Calve Perthe's disease, Osgood-Schlatter disease) is usually unilateral, occurring most frequently in only one epiphysis. It is generally accompanied with pain and does not respond to thyroid therapy.

[Ed. Note (L. D. B.).—Osteochondritis or osteochondrosis is frequently bilateral.]

Achondroplasia fetalis may be confused with cretinism clinically, but the latter may be differentiated by the unique deformities of the metaphyses and shafts of the long bones and the grossly abnormal shapes of the epiphyses.

Carl Badgley[31] advances the theory that the pathogenesis of the multiple deformities occurring in arthrogryposis multiplex congenita may best be explained on the basis of arrest of embryonic development. A primary pathologic change of the muscle, which has been proved inherent in lambs but which is of unknown origin in human beings, can well be the causative factor of this arrest. The normal rotation of the limb buds, an intrinsic characteristic of the human fetus, is carried out by the muscles of the extremity. The loss of muscle function arrests or prevents this rotation. The resultant club feet, club hands and postural deformities are the retained posture normal for the 3 month fetus but arrested from rotation into the characteristic human attitude. The rigidity of the joints is similarly the result of failure of muscle function, preventing normal fetal motion in otherwise normally developing joints.

Correction of the deformities by release operations to reestablish mobility and to continue rotation of the extremities to the normal posture of mature human extremities is the aim of therapy. The muscular damage is of course irreparable, but pronounced improvement in function can be obtained. Early treatment, with early operative correction of the deformities if necessary, is advised.

[Ed. Note (L. D. B.).—Attempts at correcting arthrogryposis deformities are sometimes most discouraging.]

Lyons and Sawyer[32] report a case of cleidocranial dysostosis in a veteran of World War I. They say that cleidocranial dysostosis is a comparatively rare congenital defect of the bony skeleton. Less than 100 cases have been reported in the literature. It is a syndrome in which the chief characteristic observation is a complete or partial absence of one or both clavicles. As so often happens, when one congenital defect is found in the body, another may also be found. In this condition one of the more constant defects accompanying that of the clavicles is a variation in the development of the bones of the skull. Barlow in 1883 reported a case of congenital absence of the clavicles and malformation of the cranium in a girl aged 2 years, probably the first typical case described. In 1897 Marie and Sainton reported 4 cases and applied the term "hereditary cleidocranial dysostosis" to the anomaly syndrome. Fitchet in 1929 made a complete survey of all reported cases in the literature. He stated that the chief features of this syndrome are grouped under four headings as follows: aplasia, more or less pronounced, of the clavicles; exaggerated development of the transverse diameter of the cranium; delay in the ossification of the fontanels, and hereditary transmission. Fitchet expressed the belief that the term "hereditary cleidocranial dysostosis" should be discontinued and "congenital cleidal dysos-

30. Blatt, M. L.; Zeldes, M., and Goodfriend, J.: Epiphysial Dysgenesis Associated with Cretinism in a Premature Infant, Am. J. Dis. Child. **67**:480 (June) 1944.

31. Badgley, C. E.: Rehabilitation in Cases of Arthrogryposis Multiplex Congenita, Arch. Phys. Therapy **24**:733 (Dec.) 1943.

32. Lyons, C. G., and Sawyer, J. G.: Cleidocranial Dysostosis, Am. J. Roentgenol. **51**:215 (Feb.) 1944.

tosis" substituted, since the condition may be either hereditary or nonhereditary, with or without other anomalies.

The clavicular deformity may vary from defects at the acromial end to complete absence of one or both clavicles. The latter is unusual, however. Most frequently it is the middle portion of the clavicle that is involved.

The defects of the skull may consist in brachycephalic changes, prominence of the frontal and parietal bosses or delay in closure of sutures and fontanels.

Most of the patients are described as being of small stature. Anomalies of dentition are common, consisting in delay in the appearance of permanent teeth, incompleteness or irregularity of the second set of teeth and a proneness to caries, missing teeth or supernumerary teeth. A high palatal arch is also rather frequent. Defects in the bones of the hands and feet, including shortening of the toes, have also been reported.

Salmon [33] reports another case of hereditary cleidocranial dysostosis in a soldier. In this case the characteristic features were partial aplasia of the clavicles, abnormal mobility of the shoulders, failure of the fontanels to close and defective union of the cranial sutures. The patient's father and sister showed evidences of the disease.

A case of Naegele pelvis associated with rudimentary femur is reported by Wahrsinger.[34] The patient had a congenital absence of the upper part of the right femur. A knee joint was present, but there was a very rudimentary lower part of the femur. An operation was performed in which the side of the ilium was turned down and the rudimentary femur was brought up against it in order to permit weight bearing of the femur against the side of the ilium. The foot was at the level of the knee, and the patient walked with an artificial limb. The pelvis showed a great deal of asymmetry. The measurements and the roentgenograms suggested that it would hardly be possible for a normal delivery to occur. However, after a total labor of twenty-three hours, the patient was delivered spontaneously of a living 6 pound 14 ounce (3,120 Gm.) girl.

Since the last part of the nineteenth century, there have appeared in the literature isolated reports dealing with the association of malformations of the nails, hypoplasia or complete absence of the patellas and deformities with impaired function of the elbows. Senturia and colleagues [35] report another case. They state that in many cases this triad has been inherited, in varying modification, in several generations of the same family, while in others one or more of the cardinal features have been absent or altered. The deformities are purely inherited or congenital and are apparently due to some developmental defect in the ectodermal and mesodermal layers of the embryo. The triad is transmitted as a hereditary dominant character and is not sex linked. A case is described in which there was the typical clinical and roentgenologic appearance, and in the patient's family tree a total of 30 persons in four generations have been similarly affected.

The clinical and roentgenologic appearance of two congenital deformities of the leg are described by Williams.[36] These are congenital angulation (kyphosis) of the tibia and congenital pseudarthrosis of the tibia (and fibula). He says that the two deformities bear a superficial resemblance in that typically there is a forward angulation or bowing in the lower half of the tibia. The treatment of both conditions is difficult, and the functional outlook is poor. There is probably little direct etiologic association of the two conditions, though the risk of development of pseudarthrosis in the deliberate corrective treatment of congenital angulation is considerable. It would appear likely that in congenital pseudarthrosis the primary defect is one of local failure of osteogenesis. In congenital angulation the primary defect may well be muscular, secondarily affecting the architecture of the bone; however, the functional association of other congenital defects (e. g., absence of the fibula and dislocation of the hip) suggests a basic mesenchymal defect which causes both a limitation of muscular growth and a failure of transitional differentiation to fibrocartilage, cartilage and true bone. Congenital absence of a normal bony structure should not be inferred from roentgenographic examination, since a structure may well be formed in cartilage though lacking in ossification.

[ED. NOTE (L. D. B.).—Beveridge H. Moore has shown a definite association between neurofibromatosis and congenital angulation and pseudarthrosis of the tibia, and his observations have been confirmed by many investigators.]

33. Salmon, D. D.: Hereditary Cleidocranial Dysostosis, Radiology **42**:391 (April) 1944.

34. Wahrsinger, P. B.: Naegele Pelvis Associated with Rudimentary Femur, Am. J. Obst. & Gynec. **47**: 427 (March) 1944.

35. Senturia, H. R., and Ben, D.: Congenital Absence of the Patellae Associated with Arthrodysplasia of the Elbows and Dystrophy of the Nails, Am. J. Roentgenol. **51**:352 (March) 1944.

36. Williams, E. R.: Two Congenital Deformities of the Tibia: Congenital Angulation and Congenital Pseudarthrosis, Brit. J. Radiol. **16**:371 (Dec.) 1943.

Bell and Grice,[37] from Boston, describe another modification of the Denis Browne splint for the treatment of congenital club feet. They have a splint which is narrower in the heel and fits the foot better and is also arched to prevent rocker bottom. They have made an improvement in the method of strapping the foot to the plate. They give the following summary:

During the treatment of 53 patients with uncomplicated congenital talipes equinovarus with the modified Denis Browne splint, several refinements in technic have been evolved to meet various problems, such as pressure sores, dermatitis, incomplete correction, persistent equinus deformity, loss of longitudinal arch and unilateral deformity. These refinements are described. Success of this method depends on the accuracy with which the foot is fixed to the splint. If properly applied, the splints will allow correction of the varus deformity and yet will maintain the longitudinal arch while obtaining full correction of the equinus deformity. Recurrence of the deformity is a constant threat, but this tendency is minimized by complete correction early and then by continued use of the splint intermittently, at least until the child begins to walk.

[Ed. Note (J. H. K.).—For the last two years I have commented at length on my experiences with the Denis Browne splint. Briefly, I have obtained better results with plaster. I have tried the method of strapping mentioned by the author and feel that it is an improvement. Denis Browne says that he has made more than fifty modifications of the splint. Still more may be expected.]

[Ed. Note (L. D. B.).—I have seen Grice apply the modified splint and have seen several of the patients. The splint and the method of applying the adhesive are great improvements in the Denis Browne technic, and any one using splint therapy should adopt these modifications.]

37. Bell, J. F., and Grice, D. S.: Treatment of Congenital Talipes Equinovarus with the Modified Denis Browne Splint, J. Bone & Joint Surg. **26**:799 (Oct.) 1944.

III. TUMORS OF BONE AND OF SYNOVIAL MEMBRANE

PREPARED BY HENRY W. MEYERDING, M.D., ROCHESTER, MINN.

A. Classification of Tumors of Bone.—Brachetto-Brian [38] presents a classification adopted by the "Comité para el Estudio de los Tumores Oseos" of the Associación Argentina de Cirugía. He discusses various phases and believes that the classification should be based on the type of tissue affected, since different cells would originate different neoplasms. The classification is as follows:

	Genetic Cells	Neoplasms Originated		Names of Tumors
A. Tumors of the skeletal sector	Osteoblast	I. Osteoblastoma	Benign	Osteoma
			Malignant	Osteosarcoma; osteogenic sarcoma
	Chondroblast	II. Chondroblastoma	Benign	Chondroma
			Malignant	Chondrosarcoma
	Myeloplax	III. Myeloplaxoma	Benign	Giant cell tumor
			Malignant	
B. Tumors of the reticuloendothelial sector	Mesoblast Histiocyte Reticuloblast Angioblast	IV. Reticuloblastoma	Benign	Reticulosarcoma
			Malignant	Ewing's sarcoma
C. Tumors of the hematopoietic sector	Mesoblast Hemohistioblast Hemocytoblast	V. Myeloblastoma		Kahler's disease; myeloma
D. Tumors of the vasculoconnective sector	Mesoblast Fibroblast Angioblast	VI. Fibroma and so forth	Benign	
		VII. Osteosarcoma	Malignant	

In the following tabulation these seven groups of neoplasms are represented with their varieties:

A. Tumors of the skeletal sector	I. Osteoblastoma	Benign	1. Benign osteoblastoma of the substantia spongiosa 2. Benign sclerosing osteoblastoma 3. Benign chondro-osteoblastoma
		Malignant	1. Malignant osteogenic osteoblastoma 2. Malignant osteogenic osteoblastoma with myeloplaxes 3. Secondary malignant osteogenic osteoblastoma 4. Juxtaconjugal malignant osteogenic osteoblastoma 5. Telangiectatic malignant osteogenic osteoblastoma
	II. Chondroblastoma	Benign	1. Chondroblastoma 2. Chondromyxoblastoma
		Malignant	1. Malignant chondroblastoma
	III. Myeloplaxoma	.....	1. Benign myeloplaxoma 2. Malignant myeloplaxoma
B. Tumors of the reticuloendothelial sector	IV. Reticuloblastoma	Benign	1. Localized reticuloendothelioma
		Malignant	1. Undifferentiated reticulosarcoma 2. Differentiated reticulosarcoma

38. Brachetto-Brian, D.: La clasificación adoptada en el "comité para el estudio de los tumores oseos," Prensa méd. argent. **28**:2185-2190 (Nov. 19) 1941; abstracted, Arch. cubanos cancerol. **3**:19-26 (Jan.-March) 1944.

C. Tumors of the hemopoietic sector	V. Myeloblastoma	Solitary	1. Plasmocellular myelosarcoma
		Multiple	1. Plasmocellular myelosarcoma 2. Myeloblastic myelosarcoma
D. Tumors of the vasculoconnective sector	VI. Fibroma and so forth	.....	1. Fibroma 2. Lipoma 3. Osteolipoma 4. Myxoma 5. Angioma
	VII. Osteosarcoma	.....	1. Fibroblastic osteosarcoma 2. Myxoblastic osteosarcoma 3. Lipoblastic osteosarcoma 4. Angioblastic osteosarcoma

B. Lesions Simulating Neoplasms of Bone.—Echternacht [39] presents a case of hemophilia in which the patient injured the tibia. Following the injury, there was tumefaction, with roentgenographic evidence of destruction of bone suggestive of a malignant lesion. Roentgen therapy was given, and later amputation was done through the knee joint, followed by hemorrhage and fatal termination.

Friedman [40] presents 4 cases of neurofibromatosis with involvement of bone. In 1 case, material obtained for biopsy from the medullary canal of the femur contained neurofibromatous tissue. He suggests that there is normally some nervous tissue present in bone marrow.

Kleinberg [41] presents a case of solitary bone cyst of the neck of the left femur in which slow progression was noted roentgenologically for a period of twenty years and in which a cure was effected by opening and curetting the cavity and packing it with bone chips.

[Ed. Note.—The destruction of the wall of the cyst will produce bleeding and promote formation of bone, but we believe that more rapid healing occurs if the cavity is packed with bone chips than if this is not done.]

Faust, Gilmore and Mudgett [42] have made a good review of the literature on chondromas, including embryology, histology and clinical picture. They present a case of a large malignant sacrococcygeal chondroma with metastasis and fatal termination.

Pavlovsky, Paterson Toledo and Muscolo [43] review the literature and present a series of 25 cases in which the patients had secondary invasion of bone with lymphogranulomatosis.

Thoma [44] presents a case of eosinophilic granuloma with diabetes insipidus in which the patient received roentgen therapy that practically healed the lesions of the mandible and in which posterior pituitary controlled the diabetes insipidus. This is the first case of eosinophilic granuloma with diabetes insipidus that has been reported, and in Thoma's mind the case links this condition more strongly with Schüller-Christian disease.

Jaffe and Lichtenstein [45] present another review of eosinophilic granuloma of bone, the previous one having been presented in 1940. They feel that it is apparently an inflammatory reaction to some unknown agent and may be single or multiple. Microscopically the cystic or granulomatous lesion shows an abundance of histiocytes and eosinophilic cells. The lesions may resolve without therapy of any kind or may heal after simple curettage. The differences and simulations between eosinophilic granuloma, Letterer-Siwe disease and Schüller-Christian disease of bone are outlined.

Osborne, Freis and Levin [46] point out that no case of eosinophilic granuloma of bone with neurologic signs or symptoms has been reported previously. They present a case of this condition, in which the complaint was paralysis of the left side of the face and later vertigo and nausea. There was roentgenologic evidence of destructive lesions of the left temporal bone, mandible, vertebrae, ribs and right femur. A biopsy was done on the mandible and the fifth rib, and examination of the tissue revealed changes typical of granuloma. Roentgen therapy was given, with complete subsidence of the neurologic signs and

39. Echternacht, A. P.: Pseudotumor of Bone in Hemophilia, Radiology **41**:565-572 (Dec.) 1943.

40. Friedman, M. M.: Neurofibromatosis of Bone, Am. J. Roentgenol. **51**:623-630 (May) 1944.

41. Kleinberg, S.: The Solitary Bone Cyst: A Report of a Case of Twenty Years' Duration, J. Bone & Joint Surg. **26**:337-343 (April) 1944.

42. Faust, D. B.; Gilmore, H. R., Jr., and Mudgett, C. S.: Chordomata: Review of Literature, with Report of Sacrococcygeal Case, Ann. Int. Med. **21**:678-698 (Oct.) 1944.

43. Pavlovsky, A.; Paterson Toledo, R., and Muscolo, D.: Linfogranulomatosis ósea; comentarios sobre 25 observaciones, Rev. ortop. y traumatol. **13**:136-157 (Jan.) 1944.

44. Thoma, K. H.: Eosinophilic Granuloma with Report of One Case Involving First the Mandible, Later Other Bones, and Being Accompanied by Diabetes Insipidus, Am. J. Orthodontics (Oral Surg. Sect.) **29**: 641-651 (Dec.) 1943.

45. Jaffe, H. L., and Lichtenstein, L.: Eosinophilic Granuloma of Bone: Condition Affecting One, Several or Many Bones, but Apparently Limited to Skeleton, and Representing Mildest Clinical Expression of Peculiar Inflammatory Histiocytosis also Underlying Letterer-Siwe Disease and Schüller-Christian Disease, Arch. Path. **37**:99-118 (Feb.) 1944.

46. Osborne, R. L.; Freis, E. D., and Levin, A. G.: Eosinophilic Granuloma of Bone Presenting Neurologic Signs and Symptoms: Report of Case, Arch. Neurol. & Psychiat. **51**:452-456 (May) 1944.

symptoms, as well as partial recalcification of some of the defects of bone.

Henschen [47] reports a case of eosinophilic granuloma, in which excision of the lesion from the left mandible of a man 24 years of age was done, followed by recurrence and second operation. He feels that every destructive lesion of bone in adolescents should be suspected of being eosinophilic granuloma.

Cavalcanti [48] reviews the literature on posttraumatic epidermoid cysts and presents a case in which there was involvement of a phalanx of the right middle finger. The lesion was excised and found to be a typical epidermoid cyst on examination.

Pohlmann and Wachstein [49] mention that epidermoid (squamous epithelial) bone cyst of the phalanges, a rare tumor of bone, has been reported as proved in only 10 cases. They present a review of the 10 cases in the literature and an additional case of their own and advocate removal of the cyst and cauterization of the cavity, measures which preserve the finger and prevent possible recurrence of the lesion.

C. Lesions of Synovial Membrane.—Moretz [50] reports 4 cases of malignant tumors arising from synovial membrane. He mentions that this type of lesion is classified according to the microscopic picture. Some lesions apparently arise from the outer layers of the synovial tissue and are indistinguishable from fibrosarcoma, and the others arise from the inner layers, thus presenting a more epithelioid type. Both types of tumor cells may be present in the same lesion. The prognosis in any case is unfavorable. Amputation is recommended except in those cases in which conditions are favorable for a wide local excision of the lesion or in those in which there is local recurrence.

D. Benign Neoplasms of Bone.—Osteoid osteoma: Stauffer [51] presents a case of osteoid osteoma, in which the lesion was excised from the head of the radius, with complete relief of symptoms. The previous pathologic report had been "healing benign giant cell tumor."

Harmon [52] presents a case of osteoid osteoma. The patient was a girl 9 years of age, and the lesion was located in the midportion of the femoral shaft. All laboratory tests gave normal results. At operation a soft gritty material was found in the cavity. Cultures revealed no growth. The microscopic examination revealed osteoid tissue between hypertrophic trabeculae with fibrous reaction and no inflammatory cells.

Kleinberg [53] reports 3 cases of osteoid osteoma, one lesion being located in the upper end of the fibula, one involving the lamina of the second lumbar vertebra and one in the neck of the astragalus. He states that the patients had complete relief of all symptoms following excision of the lesion.

Lewis [54] presents 11 cases of osteoid osteoma, in 9 of which the condition was proved and in 2 probably proved. The lesions conformed to the clinical and roentgenologic criteria of Jaffe and Lichtenstein. He advocates simple block removal of the nidus or focus of infection and feels that failure to remove all of this may cause persistence of the symptoms.

[ED. NOTE.—Such case reports as the foregoing are of increasing value and interest to physicians. Jaffe and Lichtenstein have incited a great deal of interest among surgeons, especially orthopedic surgeons, through their studies of this condition. An increasing number of case reports are evident in the literature. In the past the lesion was considered a focus of infection described as nonsuppurative osteomyelitis of Garré, Brodie's abscess or localized subcortical abscess of bone. There still exists among surgeons and pathologists a difference of opinion regarding the lesion.]

Periosteal Fibroma: Sgrosso [55] presents a case in which the patient was an 11 year old boy and the huge lesion involved the humerus. Operation had been performed unsuccessfully three months prior to the patient's admission to the hospital. The huge fibroma was removed with good results, a rare condition.

Periosteal Lipoma: Cottini [56] presents a case of periosteal lipoma of the radius, the patient being

47. Henschen, C.: Das eosinophile Granulom des Knochens, Schweiz. med. Wchnschr. **73**:451-455 (April 10) 1943.

48. Cavalcanti, J.: Cisto epidermoide post-traumático de dêdo, Arq. brasil. de cir. e ortop. **11**:36-41, 1943.

49. Pohlmann, H. F., and Wachstein, M.: Epidermoid (Squamous Epithelial) Bone Cyst of Phalanx, Ann. Surg. **119**:148-154 (Jan.) 1944.

50. Moretz, W. H.: Malignant Tumors Arising from the Synovial Membrane with Report of Four Cases, Surg., Gynec. & Obst. **79**:125-132 (Aug.) 1944.

51. Stauffer, H. M.: Osteoid-Osteoma of the Head of the Radius: Case Report, Am. J. Roentgenol. **52**: 200-202 (Aug.) 1944.

52. Harmon, P. H.: Osteoid Osteoma of Mid-Shaft Region of Femur, Am. J. Surg. **66**:128-131 (Oct.) 1944.

53. Kleinberg, S.: Osteoid Osteoma, Am. J. Surg. **66**:396-401 (Dec.) 1944.

54. Lewis, R. W.: Osteoid-Osteoma: A Review of Portions of the Literature and Presentation of Cases, Am. J. Roentgenol. **52**:70-79 (July) 1944.

55. Sgrosso, J. A.: Fibroma perióstico del húmero, Rev. ortop. y traumatol. **13**:198-204 (April) 1944.

56. Cottini, C. F.: Consideraciones sobre un caso de lipoma periostico de radio, Bol. y trab., Soc. argent. de cirujanos **4**:700-707, 1943; abstracted, Rev. Asoc. méd. argent. **57**:995-997 (Nov. 30) 1943.

a girl of 19 years. The lesion had been present for eight years, and the roentgenographic examination revealed a uniformly transparent, sharply delimited area contiguous to the upper third of the radius. The bone appeared normal. The tumor and the involved periosteum were removed. Cottini reviews the literature on this subject and states that periosteal lipoma is most commonly located in the skull.

E. Giant Cell Tumor.—Brachetto-Brian [57] presents a review of all the original reports concerning giant cell tumor in an attempt to clarify the nature of the lesion and its characteristics and to establish the relative value of the varied and confusing names that have been applied to this tumor. He proposes the name "myeloplaxoma" as the most appropriate etymologically, historically and biologically. He further proposes that Robin and Eugene Nélaton be duly recognized as the original describers of the lesion.

Samson [58] reports a case of giant cell tumor. The patient was a woman 24 years of age. The lesion appeared in the distal end of the radius. It was successfully resected, and the resulting defect was repaired by means of massive bone grafts. He describes the methods of treating giant cell tumor.

F. Vascular Neoplasms.—Anderson [59] states that the orthodox treatment of simple angioma and cavernous angioma should be discarded and roentgen treatment should not be given until the neoplasms reach full growth, at the age of 1 year, since some completely regress before the sixth year of life.

Sherman [60] reports a case of capillary hemangioma of the lower end of the femur. The affected extremity was longer than its fellow, and a roentgenogram revealed an area of radiolucency in the lower end of the femur. At operation, some periosteal reaction was found, and the medullary cavity contained sclerotic cancellous bone.

Maynard [61] states that hemangiomas may grow tremendously large and constitute a major problem and that all angiomas that are sensitive to radiation should be treated from the day they are discovered, provided they show any tendency to grow.

Kulchar [62] states that tumors of the foot, like those of the hand, are frequently multiple and discusses nine types: 1. Angiomas are mainly congenital. He describes them from the anatomic and histopathologic point of view. Many of them undergo involution spontaneously over a course of years. Angiomas of the cavernous type are treated by roentgen therapy, radium or a sclerosing substance. 2. Tumors of the angioblastoma group (sarcoma) are best treated by excision or irradiation. 3. Angioneuromyoma, or glomus tumor, was found present in the foot in a third of the cases and was treated by excision or electrocoagulation. 4. Kaposi's sarcoma is treated by irradiation but usually recurs. 5. Ganglion is treated by excision. 6. Fibroma is treated by excision. 7. Melanoma is treated by wide excision. 8. Carcinoma is relatively uncommon. 9. Sarcoma is relatively uncommon. Fibrosarcoma is the commonest form of sarcoma. It is diagnosed by biopsy and is treated by excision or amputation at the junction of the upper third with the lower two thirds of the leg.

[Ed. Note.—It should be remembered that these vascular neoplasms may be benign or malignant, and it is important that this differentiation be made. I have seen patients who have had prolonged roentgen therapy without appreciable benefit, in whose cases complete excision could have been performed successfully at an earlier stage. When the tumor is so situated and is of such size that surgical excision is impossible, then I feel that roentgen therapy should be given. Furthermore, I have operated on patients with arteriovenous fistula, in whose cases the clinical diagnosis and treatment had been for the vascular tumors.]

G. Malignant Osteogenic Sarcoma.—Meyerding [63] presents a rare case in which the patient had multiple metatarsal fractures and osteogenic sarcoma. The osteogenic sarcoma was apparently superimposed on the fracture of the second metatarsal bone. Operation had been previously performed for a nasal lesion, and a diagnosis of spindle cell sarcoma had been made. The home physician felt that the tumor of the second metatarsal bone was a metastatic lesion. The mother of the patient demanded that surgical excision be carried out. This was accordingly done, after

57. Brachetto-Brian, D.: Sobre la historia del mieloplaxoma de los huesos; tumor de Robin-Eug. Nélaton, Rev. Asoc. méd. argent. **57**:661-669 (Sept. 15) 1943.

58. Samson, A.: Traitement des tumeurs à cellules géantes du radius; résection et transplantation osseuse, Union méd. du Canada **73**:30-36 (Jan.) 1944.

59. Anderson, C. R.: Tumors of the Foot, J. A. M. A. **125**:302 (May 27) 1944.

60. Sherman, M. S.: Capillary Hemangioma of Bone, Arch. Path. **38**:158-161 (Sept.) 1944.

61. Maynard, M. T.-R.: Benign and Malignant Tumors of the Foot, J. A. M. A. **125**:990 (Aug. 5) 1944.

62. Kulchar, G. V.: Benign and Malignant Tumors of the Foot, J. A. M. A. **124**:761-766 (March 18) 1944.

63. Meyerding, H. W.: Multiple Metatarsal Fractures Associated with Osteogenic Sarcoma, J. A. M. A. **124**:228-230 (Jan. 22) 1944.

which the pathologic report was osteosarcoma. Subsequent to this, fracture of the third metatarsal bone with callus formation developed. Excision was again requested, and the lesion proved to be benign march fracture with callus formation. Still later the patient had fractures of the first and fourth metatarsal bones, which were evident on roentgenographic examination. At the time the paper was written, he was living and working in a lumber mill fourteen years following operation on the second metatarsal bone. The specimen and the tissues were reexamined by Dr. Broders and showed unquestionably that the original lesion of the second metatarsal bone was osteosarcoma and that the lesion of the third metatarsal bone was march fracture.

Gershon-Cohen and Doran [64] review the literature of fatigue-stress fractures and emphasize the necessity for ruling out systemic disease and local pathologic changes. They support the hypothesis of fatigue-stress and present 4 cases. They state that the fracture lines are thin and the callus formation is diagnostic, although they believe that the lesion could be taken for osteogenic sarcoma in the latter stages of the condition.

[Ed. Note.—My case reported at the beginning of this section illustrates the confusion which could arise by depending on roentgen interpretation alone.]

Friedman [65] reports a case of osteolytic osteogenic sarcoma of the os pubis, which is an extremely rare location. His patient was a woman 42 years of age. Roentgenographic examination revealed destruction of the right horizontal ramus of the pubic bone. The serum alkaline phosphatase was elevated to 18 units; the calcium and phosphorus levels were normal. A biopsy was done, and the pathologist's diagnosis was osteolytic osteogenic tumor of bone. Roentgen therapy was given for thirty-one months, with no essential change in the roentgenograms. The patient died of metastasis three and a half years later.

[Ed. Note.—The very rare location of the lesion in this case, in which a thorough study of the microscopic and roentgenologic findings was made and the end result was obtained, makes reports of this type of value. My statistical studies of tumors of bone have been based on facts obtained from proved microscopic changes, histopathologic determination of the grade of malignancy and subsequent follow-up of cases. Statistical reports without a report of the microscopic studies are not based on sufficient evidence of proof of malignancy and therefore are of less value in determining the benefits of treatment and prognosis than those based on microscopic studies.]

McNattin,[66] stimulated by the lack of satisfactory opinions concerning any one method of treatment of osteogenic sarcoma, reports a small series of cases in which the patients were treated by roentgen rays for from sixty to one hundred and forty treatments. The treatments were given over multiple portals, and amputation was done when the first signs of irradiation necrosis appeared. He believes that this form of therapy gives the best prognosis and that delay of amputation does not increase the likelihood of distant metastasis. He believes that if serial roentgenograms show some recession of the lesion, indicating radiosensitivity in this type of sarcoma, the total amount of irradiation may be decreased and amputation may be avoided.

[Ed. Note.—Treatment by means of roentgen rays given preoperatively followed by amputation (Ferguson) delays removal of a malignant lesion. Such a delay is contrary to the common belief that early eradication is the method of choice. Unless there is microscopic proof of the grade of malignancy, I hardly feel that the results of treatment of osteogenic sarcoma by roentgen therapy alone are acceptable.]

Osteochondrosarcoma: Haggart, Hare and Marks [67] present a case in which osteochondrosarcoma arose from the rami of the pubis and ischium. The surgical removal of the tumor was made difficult by its location, since it was adjacent to and compressing the rectum.

Kemper and Bloom [68] present a case of osteochondrosarcoma. The patient was a girl, 13 years of age. Biopsy revealed a spindle cell osteochondrosarcoma of the right tibia without metastasis, and amputation through the lower part of the thigh was done. Two years subsequently there was an osteochondrosarcoma of the femur. At this time a midthigh amputation was done. Then about five months later a maxillary tumor, a mass in the upper right quadrant of the abdomen and recurrence of the osteochondrosar-

64. Gershon-Cohen, J., and Doran, R. E.: Fatigue-Stress Fractures: Diverse Anatomic Location and Similarity to Malignant Lesions, U. S. Nav. M. Bull. **43**: 674-684 (Oct.) 1944.

65. Friedman, S. T.: Osteogenic Osteolytic Sarcoma of the Os Pubis, Am. J. Surg. **64**:248-253 (May) 1944.

66. McNattin, R. F.: Treatment of Osteogenic Sarcoma with Preoperative Roentgen Radiation in Large Doses, Radiology **42**:246-248 (March) 1944.

67. Haggart, G. F.; Hare, H. F., and Marks, J. H.: Clinico-Pathological Conference [Osteochondrosarcoma], Radiology **43**:378-382 (Oct.) 1944.

68. Kemper, J. W., and Bloom, H. J.: Metastatic Osteochondroma of Maxilla from Primary Tumor of Tibia: Report of Case, Am. J. Orthodontics (Oral Surg. Sect.) **30**:704-708 (Nov.) 1944.

coma in the femur were found. A biopsy of the mass of the maxillary region was done, and the same pathologic tissue was found, that is, osteochondrosarcoma. This was excised twice by cautery as a palliative measure. Postmortem examination three years or more following the first operation revealed retroperitoneal and sternal metastatic growths but none in the lung.

H. Metastatic Tumors.—Fibrosarcoma: Carroll and Martin [69] report on a series of 40 cases of fibrosarcoma of the extremities seen over a period of thirty years and believe that in those of longer duration (an average of ten and a half years) before treatment is started there is better progress than those of short duration. There was a history of trauma in 2 cases. The authors found that local recurrence is characteristic of this lesion unless wide excision or amputation is performed and also that metastasis to regional lymph nodes occurred in 1 out of every 8 cases. In view of this, they believe that excision of the regional nodes should be routine. They feel that irradiation of these tumors has been ineffective in their experience.

[Ed. Note.—The apparent good results in slow-growing and long-standing tumors of this class are directly dependent on the low grade of malignancy.]

Friedman [70] presents 2 cases and believes that local resection of a connective tissue type of fibrosarcoma is commonly followed by a recurrence. Postoperative roentgen therapy, even in large doses, will prevent only a small part of recurrences. He believes that the postoperative interstitial insertion of radium is the most effective method of destroying tumor cells which may remain in the region of the operation.

Olin [71] reports a case of fibrosarcoma with destruction of the glenoid cavity and apparent involvement of the head of the humerus. A shoulder girdle amputation was performed, and the pathologic examination showed fibrosarcoma. Metastasis to bone and lungs developed subsequently and resulted in death in a few weeks.

Steiner [72] presents an interesting and complete study of an unusual case of widespread multiple fibrosarcoma of bone with visceral lesions involving the reticuloendothelial system. The lesions arose almost simultaneously throughout the body in the course of a few months. A thorough postmortem study was made yet no one lesion was deemed primary.

Rhabdomyosarcoma: Garber [73] discusses the rarity of rhabdomyosarcoma and presents a verified case in which the lesion occurred in a man of 68 years. During a course of six months, pain and a progressively enlarging tumor appeared in the left shoulder. The roentgenograms revealed a destructive lesion involving the upper part of the humerus, with characteristics of osteogenic sarcoma. After a course of roentgen therapy, no regression of the lesion occurred and surgical exploration was performed. The patient was apparently well after six months.

Carcinoma: Colonna [74] emphasizes that pain appears early in carcinoma of bone and should not be ignored. He insists on a complete history, a thorough physical examination and laboratory and roentgenographic studies for determination of the diagnosis but feels that even then microscopic study and passage of time may alter an originally correct diagnosis. He further feels that the public should be educated to recognize signs, symptoms and prognosis of carcinoma of bone.

[Ed. Note.—Roentgenographic examination of painful areas will often permit early recognition of tumors and lead to a true diagnosis and treatment of a malignant lesion of bone. The grade of malignancy, as determined by the microscopic study of the tissue removed, then becomes an important factor in deciding the type of treatment and the prognosis.]

Paletta and Lehman [75] review 267 cases of carcinoma of the breast and make a comparative study of those in which there is metastasis to bone and viscera. They conclude that there is a slightly higher degree of malignancy in cases in which there is metastasis to bone than in cases in which there is metastasis to viscera.

Bertin [76] presents 3 cases in which metastatic lesions of bone were the first symptoms noticed

69. Carroll, G. A., and Martin, T. M.: Fibrosarcoma of the Extremities, S. Clin. North America **24**:1220-1227 (Oct.) 1944.

70. Friedman, M.: Treatment of Connective Tissue Fibrosarcoma with Surgery and Radium, Bull. Hosp. Joint Dis. **4**:66-69 (Oct.) 1943.

71. Olin, H. A.: Primary Malignant Neoplasm of the Shoulder Joint, with Report of a Case, Radiology **42**: 359-367 (April) 1944.

72. Steiner, P. E.: Multiple Diffuse Fibrosarcoma of Bone, Am. J. Path. **20**:877-893 (Sept.) 1944.

73. Garber, R. L.: Rhabdomyosarcoma of the Extremities, Radiology **42**:595-596 (June) 1944.

74. Colonna, P. C.: Symposium on Early Diagnosis of Cancer: Persistent Bone Pain, Tr. & Stud., Coll. Physicians, Philadelphia **12**:65-66 (June) 1944.

75. Paletta, F. X., and Lehman, E. P.: Carcinoma of the Breast: A Comparative Clinical and Pathologic Study of Tumors Metastasizing to Bone and to Viscera, Surgery **15**:944-953 (June) 1944.

76. Bertin, E. J.: Metastasis to Bone as First Symptom of Cancer of Gastrointestinal Tract: Report of Three Cases, Am. J. Roentgenol. **51**:614-622 (May) 1944.

and which later proved to be instances of primary carcinoma of the gastrointestinal tract.

[ED. NOTE.—We have had similar experience in a number of cases. The pathologist usually is able to suggest the probable primary location of the lesion.]

I. Treatment.—Phemister [77] discusses ununited fractures and defects of bone and feels that they may be satisfactorily repaired by transplantation of bone. In those instances in which an excision of bone was performed to eradicate a tumor (giant cell sarcoma, large benign tumors of bone, chondrosarcoma and so forth), the defect in the long bones was satisfactorily bridged by transplantation of bone.

[ED. NOTE.—I believe that low grade malignant lesions of bone, if recognized before they reach too great a size, and some benign lesions of bone and cysts of bone may be treated by excision and massive bone grafts with good results.]

Hormone and Castration Therapy in Carcinoma of Prostate and Breast: Middleton [78] reports a case of pathologic fracture with delayed union in the subtrochanteric region of the femur which healed after bilateral orchectomy. The patient died twenty months subsequently, apparently from cerebral vascular accident.

Watkinson, Delory, King and Haddow [79] present 10 cases of carcinoma of the prostate, in 5 of which there was roentgenographic evidence of metastasis to bone. Improvement was noted in 9 cases following therapy with diethylstilbestrol.

Ritvo and Peterson [80] present cases in which the patients had metastasis of bone from carcinoma of the breast and in which regression, noted roentgenographically, was evident after ovarian sterilization. They believe that the regression results from the withdrawal of ovarian hormone. About a third or more of their patients had pronounced relief from pain and general physical improvement, with regression of the lesions of bone noticeable on roentgenographic examination.

[ED. NOTE.—The report of these 3 papers further illustrates the clinical benefits obtained when patients with metastasis are treated by castration and administration of estrogens (diethylstilbestrol).]

J. Experimental Studies of Primary and Secondary Tumors of Bone.—Barrett, Dalton, Edwards and Greenstein [81] report on the history, cytologic and pathologic characteristics and phosphatase activity of a spontaneous, transplantable osteogenic sarcoma carried through eighteen generations of mice (at the time of writing). Early generations of subcutaneous transplants and pulmonary metastasis were osteogenic, with malignant osteoblasts, osteoid tissue and true bone. In later generations the character changed to a more rapidly growing anaplastic tumor which more closely resembled fibrosarcoma, and the capacity of the tumor to cause high alkaline phosphatase activity and to form osteoid tissue was lost or inhibited.

Dunlap, Aub, Evans and Harris [82] review some of the clinical and experimental work on ingestion and implantation of radium and radon in the production of osteogenic sarcoma. Thirteen male rats of the Wistar strain were given radium chloride for twenty days. Eight months subsequently, some objective signs of osteogenic sarcoma began to appear, and eventually osteogenic sarcoma developed in 9 of the 13 rats, with metastasis in 2. All tumor transplants except one failed because rats not of the Wistar strain were used. One transplant grew and since then has been successfully carried in about 50 per cent of attempts through seven serial generations in "Wistar" rats. The transplants have retained their original histologic characteristics and ability to form bone.

Abels and others [83] report that because heptylaldehyde bisulfite appeared toxic to human mammary carcinoma in vitro and produced liquefaction necrosis of spontaneous mammary carcinoma in mice they administered it to 14 women who had mammary carcinoma with metastasis to bone; it had no effect of any kind. They conclude that its in vitro effect is due to bisulfite which in vivo was hydrolyzed too rapidly to show any effect.

77. Phemister, D. B.: The Repair of Bone Defects and Ununited Fractures by Bone Transplantation, Proc. Interst. Postgrad. M. A. North America (1942), 1943, pp. 105-108.

78. Middleton, A. W.: Union of Pathologic Fracture of Femur Following Castrations for Carcinoma of Prostate, Am. J. Surg. **64**:144-146 (April) 1944.

79. Watkinson, J. M.; Delory, G. E.; King, E. J., and Haddow, A.: Plasma Acid Phosphatase in Carcinoma of the Prostate and the Effect of Treatment with Stilboestrol, Brit. M. J. **2**:492-495 (Oct. 14) 1944.

80. Ritvo, M., and Peterson, O. S., Jr.: Regression of Bone Metastases from Breast Cancer After Ovarian Sterilization, Am. J. Roentgenol. **51**:220-229 (Feb.) 1944.

81. Barrett, M. K.; Dalton, A. J.; Edwards, J. E., and Greenstein, J. P.: Transplantable Osteogenic Sarcoma Originating in C$_3$H Mouse, J. Nat. Cancer Inst. **4**:389-402 (Feb.) 1944.

82. Dunlap, C. E.; Aub, J. C.; Evans, R. D., and Harris, R. S.: Transplantable Osteogenic Sarcomas Induced in Rats by Feeding Radium, Am. J. Path. **20**: 1-21 (Jan.) 1944.

83. Abels, J. C.; Treves, N.; Herrmann, J.; Singher, H. O.; Kensler, C. J., and Rhoads, C. P.: The Administration of Heptylaldehyde Bisulfite to Patients with Inoperable Mammary Carcinoma Metastatic to Bone, Cancer Research **4**:438-443 (July) 1944.

Frantz, Ball, Keston and Palmer [84] present an interesting study of the effects of activity of the metastatic portions of carcinoma of the thyroid. Radioactive iodine was administered on the assumption that the tumor cells would take up iodine selectively. The postmortem reports showed that only one metastasis had consistently taken up the iodine. The radioactivity of the iodine was not clinically effective for therapeutic "internal irradiation." Possibly, larger amounts might be effective in the well differentiated tissues.

[ED. NOTE.—Such investigations as were carried out by the authors of these experimental studies are commendable, as it is through such efforts that one can look forward to solving the problem of cure of malignant lesions and prevention of metastasis.]

84. Frantz, V. K.; Ball, R. P.; Keston, A. S., and Palmer, W. W.: Thyroid Carcinoma with Metastases Studied with Radioactive Iodine, Ann. Surg. **119**:668-689 (May) 1944.

IV. CONDITIONS INVOLVING THE HIP JOINT

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Ghormley [85] presents some novel ideas that should be kept in mind when the hip is examined. He presents clearly the complete range of normal hip motions, and characteristic motion patterns of important diseases are fully described. The limit of motion in any one plane depends on the position of the limb in other planes. Normally, there is 120 degrees of flexion, and with the extremity slightly abducted and externally rotated between 0 and 20 degrees this is increased 10 degrees. The maximum of external rotation, 70 degrees, is found when the hip is slightly flexed and moderately abducted. The maximum, 40 degrees, of internal rotation is between 10 and 30 degrees of flexion and 20 degrees adduction. Ghormley uses an arthrometer to measure combined motions accurately. Certain diseases present rather characteristic patterns of motion. [ED. NOTE (J. J. F.).—Persons interested in the mechanics of the hip should resort to the original article.]

Stuck and Hinchey [86] operated on 28 dogs and transplanted various types of pedicled muscle flaps to the hip in an attempt to establish vascular connections. When the dogs were killed, the abdominal aorta was cannulated, the blood vessels of the distal half of the bodies were flushed with isotonic solution of sodium chloride and injected with radiopaque material and roentgenograms were made. The most reliable observations, however, were those based on the pathologic study of the tissue. Various types of operations were performed. In one series, a flap of the gluteus medius muscle was inserted through a hole in the lateral side of the greater trochanter. The most successful type was that in which the vastus lateralis muscle was sutured into a longitudinal slot on the anterior surface of the neck of the femur. After decalcification and staining with hematoxylin and eosin, vascular fibrous connective tissue connections showed the establishment of an intimate union between the muscle plant and the adjacent bone. The authors have used this operation in combination with vitallium cup arthroplasty, and a Smith-Peterson nail is inserted in cases of monoarticular hypertrophic arthritis and slipped femoral epiphysis. They feel that less pain is found after arthroplasty and more rapid fusion after nailing for slipped femoral epiphysis. They reserve a final appraisal until more evidence is obtained.

Milch [87] believes that "anteversion of the femoral neck" would be better called "abnormal internal torsion of the femoral shaft." He suggests the term "coxa anteverta" to define the initial stages of adolescent epiphysiolysis. "Coxa anteverta" and "anteversion of the femoral neck" represent diametrically opposite conditions. In one, the head tends to lie behind the frontal plane; in the other, in front of the frontal plane of the femur. One is due to relative external torsion of the femur in respect to the head, the other to a relative internal torsion of the femoral shaft in respect to the neck. External rotation should be prevented in the early phase of coxa anteverta. In the late stages, when osteotomy is indicated, internal rotation of the distal fragment is to be undertaken, in contrast to external rotation, which is indicated for the anteversion of congenital dislocation. For anteversion, osteotomy with external derotation of the distal fragment is effective because it overcomes abnormal internal rotation of the shaft. For coxa anteverta, internal rotation is employed.

Townsley [88] describes the internal architecture of the upper end of the femur. The newly formed trabeculae and trabeculated plates are laid down on mechanical principles to withstand the altered

85. Ghormley, J. W.: Hip Motions, Am. J. Surg. **66**:24-30 (Oct.). 1944.

86. Stuck, W. G., and Hinchey, J. J.: Experimentally Increased Blood Supply to Head and Neck of Femur, Surg., Gynec. & Obst. **78**:160-163 (Feb.) 1944.

87. Milch, H.: Coxa Anteverta Versus Anteversion of Femoral Neck, Bull. Hosp. Joint Dis. **4**:79-85 (Oct.) 1943.

88. Townsley, W.: The Architectural Structure of Upper End of Femur in Various Pathologic Conditions, J. Path. & Bact. **56**:199-207 (April) 1944.

stresses and strains. In coxa valga, the internal architecture undergoes a devolutionary change as a result of modification of the external form and is similar to that of the almost straight reptilian femur. In osteoarthritis, a new compact articular surface is formed superficial to the original one and supported by new trabeculated elements which continue the radiating lines of the original trabecular pattern. A devolutionary process, both in the external architecture and consequently in the internal architecture, takes place in the stumps of the amputated femurs after loss of the full normal function of weight bearing. In 2 specimens examined after amputation, there was an increase in the neck angle, a decrease in the length of the neck and displacement of the head of the femur laterally, backward and downward. The backward displacement represented a retorsion of the head on the neck and exposed the medial part of the anterior surface of the neck to pressure of the iliofemoral ligament and the anterior margin of the acetabulum, thus producing an extension of the articular surface of the head in this region.

Kleinberg [89] reports a case of aseptic necrosis of the femoral head following a dislocation which he believes was not associated with a tear of the round ligament. Exploration of the hip showed a normal-appearing ligamentum teres, grossly and microscopically. He believes that this case demonstrates that rupture of the ligamentum teres is not a constant occurrence in a traumatic dislocation. The author points out that in most cases in which the femoral head is deliberately dislocated from the acetabulum the round ligament is torn, but not infrequently the head can be removed from the acetabulum without rupturing the round ligament.

Salmore [90] measured the pelvifemoral angle in 100 normal persons and found that the most accurate measurements could be made with the patient in the erect position. This angle was defined by Milch as the backward opening angle formed by the axis of the femoral shaft with Nélaton's line; it is valuable in measuring the degree of hip flexion. It was found to be between 50 and 52 degrees in normal adults and children and 58 degrees in the preambulatory infant.

Wellmerling [91] discusses the management of fractures of the femoral neck in relation to certain anatomic considerations of the upper end of the femur. There are two distinct systems of trabeculae arranged in curved paths, one beginning on the medial side of the upper femoral shaft and curving upward in a fanlike radiation to the opposite portion of the bone and the other originating in the lateral portion of the upper shaft, arching upward and medially. The result of the dense converging trabeculae is a thickened anterior and medial cortex. The fracture is reduced by overtraction in adduction and fixed in a coxa valga position, thereby interlocking the fragments and restoring the normal length. The author relies on his senses and insertion of a guide wire and cannulated nail, controlled by two plane roentgenography, rather than directing devices. For fixation he uses a 5 inch (12.7 cm.) cannulated, vitallium Smith-Peterson nail. The cortex is entered just posterior to the center of the lateral aspect of the shaft and 2 inches (5 cm.) distal to the distal prominence of the trochanter with a 5/32 inch (0.4 cm.) drill. The nail is driven with a 20 degree forward inclination so that it lies in the anteromedial wall of the neck, where the converging trabeculae are the most supportive. If the nail enters the midportion or anterior to it, the nail will emerge through the anterior portion of the neck. [ED. NOTE.—In cases of oblique neck fractures with a spicule beneath the proximal fragment, abduction is usually necessary to accomplish reduction.]

Siris and Ryan [92] believe that the chances of survival are better in cases of intracapsular fractures of the neck of the femur when reduction is done immediately. The use of two machines has simplified the technic and makes draping easier. They do not permit the patients to turn on the uninjured side, because in a certain number of cases this has caused loosening of the nail.

Miller and Bishop [93] reported the case of a 76 year old patient with a fracture of the femoral neck, who died during manipulation of the hip while he was under cyclopropane anesthesia eighteen days following fracture. Autopsy revealed a pulmonary embolism which came from the femoral vein. The authors suggest that early reduction might reduce the incidence of this complication.

Weinberger [94] describes a method for converting fractures of the femoral neck into a valgus

89. Kleinberg, S.: Aseptic Necrosis of the Head of the Femur Following Dislocation of Hip, Arch. Surg. **49**:104-108 (Aug.) 1944.

90. Salmore, W.: Pelvifemoral Angle, J. Bone & Joint Surg. **26**:392-393 (April) 1944.

91. Wellmerling, H. W.: New Therapy of Hip-Nailing: Precision Technique for Intracapsular Fractures, Indust. Med. **13**:809-817 (Oct.) 1944.

92. Siris, I. E., and Ryan, J. D.: Fractures of the Neck of the Femur: An Analysis of 157 Intracapsular and Extracapsular Fractures, Surg., Gynec. & Obst. **78**:631-639 (June) 1944.

93. Miller, S., and Bishop, H. F.: Fatal Pulmonary Embolism During Manipulation of Hip Under Anesthesia, Anesthesiology **5**:300-302 (May) 1944.

94. Weinberger, M.: Modification of Lines of Force in Treating Fractures of Neck, Rev. brasil. de ortop. e traumatol. **4**:235-240 (Sept.-Dec.) 1943.

type or to a Pauwel first degree fracture. He uses strong traction, so that a diastasis is obtained, and the extremity is then brought into 140 degrees of abduction and the fracture fixed by extra-articular fixation.

Schurch,[95] in an article discussing technic and indications for treating fractures of the femoral neck, recommends two x-ray machines and a special table for performing extra-articular pin fixations. In fractures of the trochanteric region, conservative treatment may be tried if conditions are favorable, but if prolonged immobilization is not desirable extra-articular osteosynthesis is indicated.

Stuck[96] states that intertrochanteric fractures occur in older patients and are followed by a much higher death rate than fractures of the neck. They are produced by more serious injury and as a result are attended with more pain and shock. More than half the cases of trochanteric fractures occur in women. In the fractures of the femoral neck the left hip is more commonly involved, and trochanteric fractures are more common in the right hip. The author found a greater mortality in cases of trochanteric fractures. He has never seen a nonunion of a trochanteric fracture, and none has been described in case reports so far as he knows. The main problem, therefore, is to secure union in normal position without coxa vara, shortening or external rotation. Traction has the disadvantages of holding the patient in the supine position, increasing the incidence of bed sores and hypostatic pneumonia and requiring sedatives which depress the patient. Well leg traction produces much residual stiffness and weakness after the fracture is healed. Modern anesthetics, of less shocking action, have made surgical operations on older patients less hazardous. Stuck recommends internal fixation of these fractures when possible. The nursing care is simpler, position can be changed and hospitalization, pain and use of narcotics reduced. Frequent change of position in bed and freedom of movement of the legs are sufficient to reduce pneumonia. He suggests keeping the patient in bed for eight weeks to avoid circulatory disturbances. Of the 65 cases of intertrochanteric fractures, several methods of treatment were used, the most satisfactory being internal fixation and fusion at the shaft with a nail. Coxa vara developed in only 1 case, and in this case the screws were improperly applied.

95. Schurch, O.: Technic and Indications and Results for Treatment of the Neck of Femur of Extra-articular Osteosynthesis, Helvet. med. acta **10**:449-482 (June) 1943.

96. Stuck, W. G.: Treatment of Intertrochanteric Fractures of Femur, Surgery **15**:275-291 (Feb.) 1944.

[ED. NOTE (L. D. B.).—Nonunion in a true intertrochanteric fracture, if it occurs, is certainly rare. A fracture through the base of the neck may be combined with a true intertrochanteric fracture or may be misdiagnosed as an intertrochanteric fracture. Nonunion in this type of fracture occurs frequently.]

Taylor, Neufeld and Jansen[97] report 159 cases of intertrochanteric fractures treated by open reduction and internal fixation. The nail described by Neufeld consists of one piece, pressed into a V shape with a constant angle of 135 degrees. Two screws attach the plate to the lower end of the shaft. After the femur is exposed laterally, a transverse incision is made along the base of the trochanter near the linea aspera, and the vastus lateralis muscle is pulled forward, to minimize loss of blood. In 102 operative cases the mortality was 21.6 per cent, and in 114 nonoperative cases 25.4 per cent. Some of the patients with more serious fractures were not operated on, and that, of course, increases the mortality in that group. Twenty-five per cent died in the first week and 50 per cent of the remainder during the first month. The operation adds to the comfort of the patients and lessens the nursing care. There was no chronic osteomyelitis or persistent drainage in the patients operated on.

Moore[98] discusses the treatment of fractures at the base of the femoral neck and in the intertrochanteric and subtrochanteric regions, for which prolonged hospitalization and expensive nursing care have been required and which have been accompanied with pressure sores and stiffness of joints. He believes that since the introduction of internal fixation and the blade plate, in 1940, these complications have been reduced. The blade which fixes the head and neck is concave, in order to prevent slipping. In 41 patients treated by this method, he reports no operative deaths or nonunions and only 1 minor cutaneous infection.

[ED. NOTE (L. D. B.).—Note the 21.6 per cent mortality rate in the cases with operations and 25.4 per cent in the cases without operations, as reported by Taylor, Neufeld and Jansen.[97]]

At the St. Louis City Hospital Johnson[99] treated over 50 patients with intertrochanteric fractures with hanging casts. The mortality was reduced from 39.3 per cent to 18 per cent and the

97. Taylor, G. M.; Neufeld, A. J., and Jansen, J.: Internal Fixation for Intertrochanteric Fractures, J. Bone & Joint Surg. **26**:707-712 (Oct.) 1944.

98. Moore, A. T.: Blade-Plate Internal Fixation for Intertrochanteric Fractures, J. Bone & Joint Surg. **26**:52-62 (Jan.) 1944.

99. Johnson, M. D.: The Treatment of Intertrochanteric Fractures of Femur with a Hanging Cast, Surg., Gynec. & Obst. **77**:598-600 (Dec.) 1943.

duration of hospitalization was shortened. Since the authors adopted the use of a Steinmann pin through the lower part of the femur and the incorporation of the pin in the cast, as suggested by Key, the complications of pressure sores and foot drop have been eliminated. The cast is now applied with the knee in 30 to 40 degrees flexion, with plaster loops on the anterolateral aspect, incorporated at the knee and foot for traction. One to three days later the patient is placed in a wheel chair with a pillow beneath the cast, and the footboard is turned up, so that the legs hang without support. Crutches may be used in three weeks. The cast is removed after an average of forty-three and four-tenths days and the patient discharged on crutches. Complications, such as pneumonia, decubitus ulcer, stiffness of knees and ankles and weakness from lying in bed are reduced. The reductions have been found to be as good as those obtained with other methods, and nonunion has not occurred. [ED. NOTE (J. J. F.).—This method is novel in the management of these fractures and demands careful consideration. Immobilization with plaster would be expected to cause more articular stiffness than the methods now employed.]

Pascau, Ponce de Leon and Aymerich [100] obtained bony union in 55 of 59 cases of trochanteric fractures treated by traction with a Kirschner wire through the supracondylar portion of the femur. Fifty-one of these patients recovered complete function. Only 2 had a coxa vara deformity. [ED. NOTE (J. J. F.).—The recovery of function of the knee following traction in this age group is usually slow, and not uncommonly some permanent limitation of motion results. The incidence of coxa vara reported in this paper is unusually low, as compared with that in other reports.]

Leadbetter [101] describes an osteotomy high in the cervical axis which is accomplished under full vision and avoids the ascending ramus of the femoral nutrient artery as well as the cervical branches of the circumflex femoral artery. The apposition of abundant cancellous bone is established, with positive pressure beneath the capital portion of the bone in a true valgus position. The osteotomy is made through an anterior approach. The capsule is opened by a cruciate or a semilunar incision, and any comminuted or projecting fragments at the lower part of the head are removed. The osteotomy is done in the long axis at the junction of its middle and upper thirds, and the neck is then displaced beneath the head to a point within the lower acetabular rim. During the fourth week, the plaster is bivalved and massage and quadriceps-setting exercises begin; the plaster is removed in eight weeks. Eight patients were operated on and observed for at least one year. Every patient had a functioning and weight-bearing hip, and solid union occurred in 6. [ED. NOTE (J. J. F.).—This operation seems promising. Its value will be more accurately determined when more cases are reported. The early quadriceps exercises help to reduce the disability caused by stiffness of the joint.]

Schneider [102] discusses nonunion of the femoral neck and the difficulties encountered with the various present day methods of treatment. He has not found the Blount blade plate fixation for osteotomy, performed for nonunion, to be the entire answer, as in some cases the plate will pull out anteriorly as the extremity goes into external rotation or the screws loosen from the atrophic bone. The Smith-Peterson nail with the Thornton plate has been more satisfactory in his hands, but this method does not always suffice unaided by external support. [ED. NOTE (J. J. F.)—This complication is not as frequent when the plate is introduced in the location used for internal fixation as it is when the plate is introduced high in the trochanteric cancellous bone.]

Rowe and Ghormley [103] state that while most authors believe that bone grafting yields the best end results in the treatment of nonunion of the femoral neck it is well known that only a small percentage of the cases meet the indications for this operation. While many have expressed the opinion that osteotomy offers the simplest and safest procedure for the patient who presents a poor risk and the ones not suitable for osteosynthesis, the authors believe that better mechanical function can be attained by the use of one of the reconstructive operations if the condition of the patient does not prohibit it. If the head is nonviable, the Whitman, the Colonna or the Albee procedure is indicated. If the head is viable and the degree of absorption rules out a bone-grafting procedure, then the Brackett operation is indicated. A single long vitallium screw, fix-

100. Pascau, I.; Ponce de Leon, A., and Aymerich, E.: Nonsurgical Therapy of Fractures of the Trochanteric Region, Cir. ortop. y traumatol., Habana **11**:19-29 (Jan.-June) 1943.

101. Leadbetter, G. W.: Cervical-Axial Osteotomy of Femur: A Preliminary Report, J. Bone & Joint Surg. **26**:713-720 (Oct.) 1944.

102. Schneider, C. C.: Sequelae of Fractures of Neck of Femur and Their Treatment, Wisconsin M. J. **43**:799-804 (Aug.) 1944.

103. Rowe, M. L., and Ghormley, R. K.: Brackett Operation for Ununited Fractures of the Neck of the Femur, J. Bone & Joint Surg. **26**:249-256 (April) 1944.

ing the trochanter and head to the neck, was used in 11 cases in which the Brackett operation was performed, and in 10 results were regarded as good. Ability to walk without support and possession of a practical range of painless motion were obtained in 67.7 per cent of 34 cases. If the articular surface has been destroyed or is ankylosed to the acetabulum, the operation should not be attempted.

McGehee,[104] in discussing the end results of subtrochanteric osteotomy for nonunion of the femoral neck, suggests preliminary traction if the lesser trochanter is above the lower border of the head. The osteotomy is made slightly oblique and at the lower border of the head, just above the lesser trochanter, so that when the medial shift is made the upper portion of the femoral shaft is in direct contact with the greater trochanter and the femoral head. A dead head was not considered a contraindication for operation. Knee hinges with passive motion to 45 degrees were suggested in certain cases to minimize stiffness of the knee. Thirty-eight patients were followed from one to six years postoperatively, and 65 per cent could walk without support and had a good range of motion with little or no pain.

Merle d'Aubigné[105] is of the opinion that it may be possible after several months to accomplish reduction in some cases of intracapsular fractures of the neck of the femur and to repair them with fixation by extra-articular nailing. For fractures that are not reducible, osteotomy has given satisfactory results.

Speed and McGehee[106] report on 52 cases of nonunion of fractures of the neck of the femur treated by subtrochanteric osteotomy and give the final results in 38 cases. The advantages are simplicity and absence of shock in the aged. It may be done for nonunion of long standing and in the presence of a dead head. A cast reaching to the knee, passive motion to 45 degrees as soon as postoperative tenderness subsides and physical therapy are of value in reducing stiffness of the knee in some cases. There were 89.46 per cent favorable results.

Ossman and Brooke[107] review the literature on the various types of operations devised for the treatment of nonunion of the femoral neck with bone graft and internal fixation. They reported 2 cases with successful results, using a Smith-Peterson nail with a fibular graft. If necessary, preliminary skeletal traction is used. A viable head with minimal absorption of the neck should be a prerequisite.

Harmon and Adams[108] have analyzed the end results in 132 cases of pyogenic coxitis, in order to determine the factors that would lead to the best functional results. They found a relatively benign course in extremely young persons, in older persons, in whom the involvement of bone was restricted, in persons of other age groups in which the bone lesion was small and in persons treated by early arthrotomy and prolonged traction. The greatest disability occurred in cases of pyogenic coxitis following extensive osteomyelitis. The end result, a stable, painless, movable hip, is more desirable than an ankylosed hip, for it may function for many years before pain occurs. Even when epiphysialysis and loss of portions of the head and neck occurred, extension was often followed by a favorable outcome. Early diagnosis by aspiration of joint fluid is recommended. Chemotherapy is started immediately after the diagnosis.

Ghormley[109] emphasizes the importance of proper management of several conditions that eventually result in hypertrophic arthritis of the hip. Patients with suppurative arthritis will have a more favorable outcome following the administration of chemotherapy. Slipping of the capital femoral epiphysis should be diagnosed and treated in the preslipping stage. Open reduction of congenital dislocations of the hip, shelving operations for congenital aplasia, perfect reduction of the hip in fractures of the acetabulum and guarded weight bearing will reduce the incidence of hypertrophic arthritis. The treatment depends on occupation, age and general health. Reduction of weight in obese persons should be considered. Patients are taught to minimize strain and to prevent symptoms by the use of heat, cane and crutches. Arthrodesis relieves pain, but patients

104. McGehee, F. O.: Subtrochanteric Osteotomy for Non-Union Fractures of Neck of Femur: A Report of Fifty-Two Cases with End Results of Thirty-Eight, M. Rec. & Ann. **38**:809-813 (June) 1944.

105. Merle d'Aubigné, R.: Therapy of Old Fractures of Neck of Femur and Pseudarthrosis, J. de chir. **58**:81-97, 1941-1942.

106. Speed, J. S., and McGehee, F. O.: Subtrochanteric Osteotomy for Non-Union of the Neck of Femur: A Report on Fifty-Two Cases with Final Result in Thirty-Eight, Cir. ortop. y traumatol., Habana **11**:47-56 (July-Dec.) 1943.

107. Ossman, L. N., and Brooke, W. S.: Combined Smith-Peterson Nail and Fibular Bone Graft in Treatment of Fractures of the Neck of Femur, Rocky Mountain M. J. **41**:814-818 (Nov.) 1944.

108. Harmon, P. H., and Adams, C. O.: Pyogenic Coxitis: End Results and Considerations of Diagnosis and Treatment, Surg., Gynec. & Obst. **78**:371-390 (April) 1944.

109. Ghormley, R. K.: Etiology and Indications for Treatment of Hypertrophic Arthritis of the Hip, Proc. Staff Meet., Mayo Clin. **19**:559-560 (Nov. 29) 1944.

are not usually willing to accept it, and it is contraindicated when both hips are involved and when the spine is affected. Cup arthroplasty may offer hope of retaining motion and relieving pain in certain cases.

Bergmann [110] discusses aseptic bone necrosis in lesions of the hip. In fractures of the femoral neck, the arteries running along the inner lining of the capsule and entering the head are destroyed, leaving only the vessels of the round ligament, which are insufficient in most instances to keep the head from undergoing necrosis. The adjacent living bone of the distal fragment unites with the head before it has gone through all the stages of reorganization. The endosteum of the distal fragment is the only source from which new bone is laid down, and this is inferior to periosteal callus. The pathologic changes of Perthes' disease (osteochondrosis of the capital epiphysis of the femur), congenital dislocation of the hip and caisson disease are discussed and illustrated with roentgenograms and photographs. [ED. NOTE (J. J. F.).—One interested in the pathologic changes of aseptic necrosis of the head of the femur should read this well illustrated article. In fractures of the femoral neck, there often remains a significant blood supply from the posterior capsular vessels.]

Stephens [111] reviews the literature on iliopectineal bursa and adds 2 cases to the literature. The globular mass may be confused with an enlarged inguinal node or a femoral hernia. Aspiration of seromucous fluid will differentiate it from the former, and pulsation on top of the tumor will distinguish it from the latter. A psoas abscess is more fluctuant. Unilateral chronic disease of the hip joint on the involved side suggests a possible associated bursitis. The simplest method of treatment is aspiration followed by administration of sclerosing solutions. If suppuration occurs, incision and packing are advocated.

Pusitz [112] believes that serious gunshot wounds of the hip and buttock with much fragmentation of the head, seen late, are best treated by resection of the femoral head, sulfonamide compounds and Orr's treatment. A reconstruction or arthrodesis may be performed subsequent to the control of the infection. In cases in which there is much destruction of tissue and in which a portion of the sciatic nerve is lost, débridement removal of bone and, later, disarticulation of the hip may be indicated. One such case is reported in detail.

Watson and Berkman [113] state that failure to recognize march fractures of the femoral neck promptly may result in serious disability and deformity. They report the case of a soldier 34 years old who experienced sudden severe pain in his hip while hiking and a few days later had pain on the inner side of his thigh and knee. He continued activity, and one month later roentgenograms showed an incomplete fracture with shortening and limited motion of the hip. He was treated by traction for two weeks and then used crutches, without weight bearing, for four months.

Harmon and Adams [114] review the end results of surgical reconstruction in 53 patients who previously had had acute pyogenic arthritis. Chronically discharging sinuses responded satisfactorily to treatment in 80 per cent of the cases. Positional correction of an ankylosed hip, ankylosis of a painful hip and certain plastic procedures performed on young persons were found to be more satisfactory than arthroplastic procedures. Excision of the major part of the ilium in certain cases was thought to be of value when this portion of the pelvis was affected. Disarticulation of the hip joint should receive more consideration in the treatment of persistent suppuration of the hip joint in adults in the presence of osteomyelitis in the upper half of the femur. For young persons with unilateral instability of the hip joint the shelf operation is the procedure of choice, while for adults surgical arthrodesis is performed at the level of the acetabulum after the replacement of the dislocated hip. [ED. NOTE (J. J. F.).—This article is well illustrated and many data are tabulated. Interested persons should refer to the original.]

Milch [115] is of the opinion that the angle of abduction is an unsatisfactory guide in performing an upper femoral osteotomy, and the postosteotomy angle is suggested instead. This angle represents the angle of the neck of the osteotomized femur and is measured by the line of the shaft and the line running from the upper end of the osteotomized shaft to the femoral neck.

110. Bergmann, E.: Role of Aseptic Bone Necrosis in Hip Lesions, Am. J. Surg. **63**:218-235 (Feb.) 1944.

111. Stephens, V. R.: Tumor of Iliopectineal Bursa: Two Cases, Arch. Surg. **49**:9-11 (July) 1944.

112. Pusitz, M. E., and Taylor, R. M.: Serious Gunshot Wounds of Hip, J. Kansas M. Soc. **44**:397-400 (Dec.) 1943.

113. Watson, F. C., and Berkman, E. F.: Fatigue (March) Fractures of Femoral Neck, J. Bone & Joint Surg. **26**:404-405 (April) 1944.

114. Harmon, P. H., and Adams, C. O.: Pyogenic Coxitis: Indications for Surgical Treatment in Residual and Chronic Stages and End Results of Reconstruction in Fifty-Three Patients, Surg., Gynec. & Obst. **78**:497-508 (May) 1944.

115. Milch, H.: The Postosteotomy Angle, J. Bone & Joint Surg. **26**:394-400 (April) 1944.

This angle should not be made greater than the angle of inclination of the outer wall of the level pelvis unless limitation of motion is desired. The postosteotomy angle is greater for any given degree of abduction in the bifurcation operation than in any other type, giving limited motion, and is indicated for tuberculosis and coxitis and contraindicated for congenital dislocation of the hip, fractures of the femoral neck, benign arthritides and all conditions in which motion is desired. The postosteotomy angle can be reduced below the critical value of the level pelvic wall by reducing the degree of abduction of the osteotomized fragment or by resecting the medially projecting apex of the postosteotomy angle. The average angle of inclination of the pelvic wall has been found to be between 205 and 210 degrees. The postosteotomy angle must not be increased beyond this measure if the maximum stability without limitation of mobility is desired.

Bickel and Ghormley [116] find that the results of cup arthroplasty have not been uniformly satisfactory, but in patients who are severely disabled because of pain, deformity or limited motion the results are sufficiently encouraging to justify the operation. Vitallium is the best material yet found to use as a mold. The lucite cup has been discarded because it wears and breaks, necessitating removal. Shortening of the femoral head and neck was observed in many cases when roentgenograms were compared with those taken six months later; in some cases it was so extensive as to allow the cup to ride on the base of the neck against the trochanter and shaft, but the results were no worse. The most disappointing results were obtained in patients operated on for aseptic necrosis. They were poor in over one half of the cases. The results for rheumatoid arthritis were better in men and in operations done on one side. The authors do not advocate operation until the sedimentation rate approaches normal. Eighty-eight of 91 patients were followed from eight months to five years. Only a few felt that they were worse than before the operation. [ED. NOTE (J. J. F.).—The authors have given a thorough appraisal of arthroplasty, and one should read the original article in order to obtain a detailed report.]

Spira [117] reports the case of a boy unable to stand, even when supported, because of poliomyelitis. Contractures were released by surgical operation, and a strip of fascia lata was brought through a hole in the trochanter and through another hole in the superior pubic ramus and attached to itself, with the extremity held in internal rotation so that the hip could be swung in one plane. The author states that the patient was considerably improved.

Kennedy [118] states that traumatic separation of the upper femoral epiphysis is rare. He reviews 20 cases from the literature, and adds 1. The injury occurs during podalic version and breech extraction or breech presentation and extraction. The case reported by the author is the first reported with cephalic presentation and is the only reported case of bilateral injury. Rotary movements combined with traction on the leg usually produce the injury. The clinical signs are swelling, slight shortening, external rotation, limitation of active motion, painful passive motion and sometimes discoloration and crepitation. The roentgenograms show upward and outward displacement of the proximal end of the diaphysis, profuse callus formation, premature ossification of the capital epiphysis and a prominent subperiosteal reaction around the upper end of the shaft. In cases of severe injury a coxa vara may result. Serial roentgenograms were found of great value in the diagnosis and management.

Haines [119] found that fracture of the acetabulum is an uncommon complication of convulsive therapy. He found 3 cases in the literature and added another. The patient was a boy of 17. A loud snap was heard when convulsions began. Roentgenograms showed a thin-walled acetabulum resembling an Otto type of pelvis, with protrusion of the head. The author has found that complications can be reduced to such a negligible degree by restraints that it is not necessary to use curare, as advocated by others.

Hammond [120] believes that posterior dislocation of the hip associated with a fracture of the acetabulum is the result of considerable trauma applied to the anterior aspect of the knee in the direction of the long axis of the femur when the hip and knee are flexed 90 degrees. An accurate reduction is essential, even if it necessitates open reduction, in order to reduce the incidence of traumatic arthritis. If aseptic necrosis occurs,

116. Bickel, W. H.; Ghormley, R. K.; Coventry, M. B., and Mussey, R. R., Jr.: Cup Arthroplasty, Proc. Staff Meet., Mayo Clin. **19**:561-568 (Nov.) 1944.

117. Spira, E.: Restoration of Walking Capacity After Paralysis of Trunk and Leg Muscles: An Operation Restricting the Hip Joint to Movements in Two Axes, Bull. Internat. Coll. Surgeons **7**:59-62 (Jan.-Feb.) 1944.

118. Kennedy, P. C.: Traumatic Separation of Upper Femoral Epiphysis, Am. J. Roentgenol. **51**:707-719 (June) 1944.

119. Haines, H. H.: An Unusual Complication of Convulsive Therapy, Psychiatric Quart. **18**:273-277 (April) 1944.

120. Hammond, G.: Posterior Dislocation of Hip Associated with Fracture, Proc. Roy. Soc. Med. **37**: 281 (April) 1944.

weight bearing is delayed until the dead bone has been replaced. Vitallium cup arthroplasty may offer favorable results in certain cases complicated by traumatic arthritis and aseptic necrosis. [ED. NOTE (L. D. B.).—This report should be compared with that of Bickel and Ghormley.[116] The most disappointing results were obtained when operation was performed for aseptic necrosis.]

Wolin [121] describes the case of a man with a Charcot joint who was treated for a dislocation of the hip following a fall; shortly after treatment the dislocation recurred. Roentgenograms showed nothing abnormal, except for the dislocation, until one year later, when a fracture with disorganization of the femoral head was found.

121. Wolin, I.: Tabetic Arthropathy of Hip, Radiology **42**:79-80 (Jan.) 1944.

V. CONDITIONS INVOLVING THE FOOT AND ANKLE

EMIL D. W. HAUSER, M.D., CHICAGO, AND ROBERT P. MONTGOMERY, M.D., MILWAUKEE

Dew and Wooten [122] present a series of 58 march fractures of the metatarsal bones involving 55 trainees. The majority of patients failed to disclose any preexisting pathologic condition of the feet. March fractures are attributable to the carrying of heavy full field equipment and marching of distances longer than 6 miles (9.6 km.) on a hard surfaced road. Local treatment of mild fractures consists in the use of an ice bag for seventy-two hours, a whirlpool bag, a daily massage and crutches; moderate weight bearing within pain limit is allowed. Splinting of any form is not advised because of the ensuing stiffness of the foot and the increasing morbidity. The prophylactic measures advanced by the authors have materially lowered the high incidences of march fracture. They recommend gradual lengthening of the march, progressive increase of field equipment and, what is most important, marching on the soft shoulders of the roads or across the fields.

Krause and Thompson [123] report the results of a study of 200 soldiers who sustained 220 march fractures of the metatarsals between May 1941 and August 1943. Special attention is given to possible predisposing factors, and the various theories which have been advanced to explain the pathogenesis of these fractures are discussed. The immediate cause of the fracture is the rhythmically repeated, subthreshold traumas incident to marching, which, acting by summation, reach a point beyond the ability of the bone to bear stress. Fatigue of the calf muscle causes these subthreshold injuries to be accentuated. The clinical observations and roentgenologic appearances are described in detail. Conservative treatment restores these men to duty with a minimum of time lost.

122. Dew, W. A., and Wooten, J. H., Jr.: March Fractures: A Series of Fifty-Eight, Mil. Surgeon **95**: 356-359 (Nov.) 1944.

123. Krause, G. R., and Thompson, J. R., Jr.: March Fracture: An Analysis of Two Hundred Cases, Am. J. Roentgenol. **52**:281-290 (Sept.) 1944.

In a study of a series of 82 cases of march fracture, Kernodle and Jacobs [124] felt that physiologic inadequacy of these feet was a factor even in their series, although they could not demonstrate any gross mechanical inadequacy. The fatigue element with loss of elasticity of the foot has been observed repeatedly and would expose the bony elements to more direct strain. The authors mention a suggestion that march fracture is based on the torsion mechanics of the foot and is due to an acute sinking of a previously well formed foot. Under stress, the medial portion of the anterior part of the foot gives way, and weight bearing is shifted to the second and third metatarsals, which become traumatized and may ultimately break down.

The treatment is varied according to the stage of the fracture when seen. If the period is less than two weeks, a short leg cast molded under the metatarsal heads is applied and a walking rubber attached for a period of three to four weeks, followed by physical therapy for a week, and a metatarsal sponge pad is worn in the shoe. If the time is three to five weeks and there is moderate callus formation, simple pads and physical therapy with moderate rest suffice.

Tyner and Hileman [125] studied 166 cases of march fracture, securing accurate information as to the time the fracture occurred after the beginning of the march, the foot involved and the metatarsal involved. The blood chemistry was studied in 12 cases. Three cases are reported in detail. They believe that the most important factor in the production of these fractures is the increased stress on the metatarsal bones, induced by muscular fatigue.

According to Breck and Higinbotham,[126] march fractures are felt to be due to crystalliza-

124. Kernodle, H. B., and Jacobs, J. E.: Metatarsal March Fractures, South. M. J. **37**:579-582 (Oct.) 1944.

125. Tyner, F. H., and Hileman, W. T.: March Fractures: An Analysis of One Hundred and Sixty-Six Cases, Am. J. Roentgenol. **52**:165-172 (Aug.) 1944.

(Footnotes continued on next page)

tion of the calcium phosphate in the bone, similar to the process occurring in metals subjected to intermittent stress, and in this condition the result of excessive minute springing or bending from prolonged marching. A simple treatment consisting in the use of crutches for four weeks from the date of fracture is advocated, with complete restriction of weight bearing during that time. Theoretic and practical considerations to support this method of treatment are given. A series of 54 cases is presented, 48 with excellent results, 5 with poor results (in soldiers with previously symptomatic poor feet) and 1 with a questionable result.

In a statistical study of 47 patients, Leavitt and Woodward [127] discovered that many accepted concepts were disproved and that patients had serious disability which tended to be recurrent and prolonged as a result of march fracture. Many were lost to the combat unit permanently. Training is most important. Foot and general conditioning can be obtained as effectively on soft or natural ground as on hard. Combinations of training on hard and on soft surfaces should be arranged to properly adjust these factors. At present the authors believe that early diagnosis and treatment by absolute freedom from weight bearing until soreness disappears may give the best results. The end results reported in this study have been poor. The authors conclude that march fracture in soldiers is more serious than other reports have indicated. Most patients returned to light duty with their organizations while wearing unpadded plaster casts. They appeared to do little better than patients with unrecognized or late untreated fracture or the few patients who, though seen early, were untreated by choice. These poor results appeared despite the fact that weight bearing in plaster is one of the accepted forms of treatment.

Eddy's [128] discovery of 3 cases of march fracture among women of a shell-loading plant during an eighteen month period prompted him to bring it to the attention of industrial physicians. In these cases the fractures developed after work involving long hours of walking or standing on concrete floors. Treatment consists in immobilization in a boot cast fitted with a walking iron. The cast is worn six weeks, and roentgenograms should show firm callus before the patient is allowed to walk on the foot. With a properly fitted cast these employees are able to continue their work. The author points out that the question of compensability arises. In this type of case the problem is extremely difficult, as it does not fulfil the requirements of an accident. In his state, however, the compensation act provides for the payment of compensation in all injuries received by an "employee in performing services arising out of and incidental to his employment." Under this interpretation of the law it has been advised that these cases can be accepted under the compensation act.

From a study of 307 cases of march fracture, Bernstein and Stone [129] concluded that prior to the introduction of "speed hikes" and prolonged marches in the curriculum of basic training, this fracture was a rare entity. Soon after this change in the curriculum occurred, this syndrome was seen. The pathologic condition occurred in soldiers irrespective of age, height, weight and general body build. No usual or unusual deformities of the foot were associated with this condition. One or more of the metatarsal bones may be involved at the same time or at different times during the same training cycle. There is no relation between preinduction occupation and development of a march fracture. Contrary to general opinion, this condition occurs in Negro soldiers, although not nearly so frequently as in the white soldiers. In the authors' opinion, the treatment of a march fracture of the foot by immobilization in a plaster of paris bandage is not indicated. These authors use a steel bar from ½ to ⅝ inch (1.3 to 1.6 cm.) wide, ⅛ inch (0.3 cm.) thick and 6 inches (15 cm.) long, countersunk into the sole of the shoe on the under side or non-weight-bearing surface of the sole and held in position by four rivets. The relief obtained by this means is definite and becomes more noticeable after several days, that is, as soon as the patient becomes accustomed to walking with a stiff-soled shoe. In this way the patient may continue the greater part of his basic training with little handicap. Most patients continue with their full training and are rarely hospitalized. Occasionally the patient obtains further relief by having a felt pad placed along the longitudinal arch in order to redistribute the weight. The steel bar is kept in position for approximately four to five weeks, at which time

126. Breck, L. W., and Higinbotham, N. L.: March Fracture: New Concepts of Etiology and Logical Method of Treatment, Mil. Surgeon **95**:313-315 (Oct.) 1944.

127. Leavitt, D. G., and Woodward, H. W.: March Fracture: A Statistical Study of Forty-Seven Patients, J. Bone & Joint Surg. **26**:733-742 (Oct.) 1944.

128. Eddy, J. H., Jr.: March Fracture in Industry, New Orleans M. & S. J. **97**:171-173 (Oct.) 1944.

129. Bernstein, A., and Stone, J. R.: March Fracture: A Report of Three Hundred and Seven Cases and a New Method of Treatment, J. Bone & Joint Surg. **26**: 743-750 (Oct.) 1944.

the fracture has solidly healed. The metal bar can then be removed and used again.

Clement [130] reports a study of 32 cases of march fracture in which the fracture was oblique in all early cases and the second and third metatarsal bones only were involved; these were longer than the first metatarsal bones in all but 2 cases, and the fracture line appeared on the medial surface in 29 cases. The increased length of the second and third metatarsal bones deranges the normal tripod structure of the foot, and march fracture results from stress and strain as a result of leverage on the bones, muscle pull of the lumbricalis and interosseus dorsalis muscles, which become spastic from irritation induced by marching.

Bosshardt [131] states that the high incidence of march fracture in German and Swiss armies is due to rigid cadence of marching. There is a definite difference between the occurrence in these two armies and that in the French army, which has an easy marching rhythm. American soldiers generally have led sedentary lives and have poor muscle tone and are therefore liable to have march fracture. The author believes that the fracture is primary and is related to a preexisting static disturbance of the foot, on which rhythmically repeated subthreshold mechanical insults have been acting. The treatment consists in rest and in physical therapy which incorporates exercises especially for dorsal and plantar flexion at the metatarsophalangeal joints.

Salmon's [132] report is based on 5 cases of march fracture. He relates that the absence of a history of direct trauma is responsible for some missed diagnoses. The characteristic appearances of the bone changes in the roentgenograms are described. Immobilization and rest are the suggested therapeutic measures.

Hullinger and Tyler [133] report 313 cases of march fracture in recruits undergoing training. The series includes a small number of cases of stress fractures in bones other than the metatarsals. It is believed that in 100 additional cases there were early march fractures which were completed by a definite trauma, but these cases have not been included in the series. A detailed statistical analysis is made of the possible relationship of age, weight and other factors to the causation of the condition. The most interesting conclusion is that there is no predisposition to march fracture by any anatomic defect or variation, either acquired or congenital. The roentgenograms in the present series have been compared with three hundred roentgenograms of feet chosen at random. Measurements were taken of metatarsal length, width and spacing; position and conformity of sesamoid bones; length and width of feet, and general formation of foot. "There was no essential difference in the average of measurements in the two groups."

The general conclusion is that march fractures are brought about by trauma in the form of repeated subthreshold insults to the bone caused by walking. The determining factor is essentially a physiologic weakness secondary to fatigue. The incidence of march fractures is directly related to the severity of the training program. A new training order increasing the load carried by a man and the amount of exercise taken immediately resulted in a sharp increase in the number of patients with march fractures admitted to the hospital. The authors favor treatment by immobilization in a light walking plaster cast. They believe that if the bone is not protected from strain in this way callus will be excessive and recovery delayed. With treatment as outlined, all but 2 of the subjects returned to the full rigorous training program in an average of thirty-three days from the time of diagnosis.

[ED. NOTE.—The incidence of march fracture has increased because of the war so that it dominates the literature on the foot. The various reports seem to be in accord with regard to the history, symptoms and findings. There is some variation with regard to causation, but most authors feel that the change in the bone is a matter of strain and that there is an imbalance between the capacity of the bony structure and the demand made on these structures. The result is a disturbance which leads to the hypertrophic changes and the actual fracture. The treatment varies somewhat, although the consensus seems to be that more protection is needed, particularly in the acute phase. The rehabilitation of the foot to gain maximum capacity, so that the patient can carry out the duties of a soldier as soon as possible, is also stressed. This can be accomplished by means of walking casts or by means of a new device, a longitudinal steel bar in the shoe. This seems to fulfil the prerequisites of protection of the metatarsal bone and early resumption of activity.]

130. Clement, B. L.: March Fracture: A Common Disability of the Foot, J. Bone & Joint Surg. **26**:148-150 (Jan.) 1944.

131. Bosshardt, C. E.: March Fracture: A Common Disability of the Foot in Military Practice, Arch. Phys. Therapy **25**:41-44 (Jan.) 1944.

132. Salmon, J. K.: March Fracture, J. Roy. Nav. M. Serv. **30**:1-5 (Jan.) 1944.

133. Hullinger, C. W., and Tyler, W. L.: March Fracture: Report of Three Hundred and Thirteen Cases Bull. U. S. Army M. Dept., September 1944, no. 80, pp. 72-80.

Hullinger [134] states that at Camp Wheeler 71 cases of proved fracture of the calcaneus bone were observed in 53 patients in less than a year. These fractures resulted from the "toughening up" of the training program. Treatment included rest, avoidance of weight bearing on the heels and physical therapy. Later, felt heel inserts or rubber heel elevations or both were used. After a period of eight to ten weeks the men were able to return to full military duty. No recurrences were observed. [ED. NOTE.—This is an interesting report, particularly in the great number of cases that were observed. We have seen such fractures only rarely; it is possible that they may have been overlooked.]

A case report is presented by Raisman [135] of a spontaneous fracture through the apophysis of the right calcaneus bone which occurred in a middle-aged woman with a previous history of syphilis.

Bingham [136] states that 10 per cent of the soldier patients in a designated army camp who complained of painful feet were found to have Morton's syndrome, which is the result of a developmental shortening or relaxation of the first metatarsal segment of the foot. A compensating insole, consisting of a weight-bearing platform for the first metatarsal bone, permitted 76 out of 100 soldiers to continue full military duty.

According to Ilfeld,[137] the observations in a group of 75 white soldiers who were admitted to the orthopedic service with complaints referable to the feet and subsequently discharged from the service were compared with similar observations obtained on examination of 347 white soldiers who were admitted to the orthopedic service with complaints referable to the feet and subsequently discharged from the service with no subjective symptoms. The majority of the men receiving discharges had a so-called third degree pes planus. Seven men of the normal group also had a third degree pronation. It was suggested, therefore, that pronounced pronation may be present without symptoms. Of the 75 men discharged, 48 gave a history of previously using supports; 46 also had backache, and 54 had pains in the knees. The treatment for pes planus used consisted of properly fitting shoes with individually fitted leather insoles to which were glued pieces of felt for support under the longitudinal and under the transverse arches and foot hygiene. The felt pads were adjustable.

Harris [138] presents numerous cases of various structural defects in the feet and evaluates them relative to the symptoms of the individual case. The article is in the form of a written report on a clinical presentation of cases.

Morton [139] discusses the biomechanics of the foot and its relation to functional disorders and deformities. He describes the evolutionary development of the foot and then shows the relationship of gravity and normal function of the foot. The structure of the foot is primarily concerned with the reaction toward the force of gravity. The relationship of gravity in standing, as well as in walking, is thoroughly worked out. The importance of the anatomic structures as supportive mechanisms against gravity is studied by means of roentgenograms, as well as by barographs and kinetographs. The instrumental analyses have led Morton to the conclusion that gravity is the only mechanical force capable of producing harmful or destructive disorders and deformities of the feet. Imperfections in the skeleton of the foot are direct and immediate sources of disordered function. Through such imperfections the abnormal dissemination of weight stresses and strains permits gravity to exert injurious effects on the overloaded parts. Correction of pedal disorders and deformities requires a clear knowledge of the normal interaction of the feet with the force of gravity so that logical therapeutic procedures can be arrived at.

What Bettmann [140] terms a functional-anatomic analysis, the regaining and maintenance of the originally predominant grasping function of the human foot, is stressed. It is emphasized that exercises for the foot should not be given without accompanying instructions for correct posture in general. Analysis is based on a supinated position for the os calcis in addition to the exercises for the "arch preserver units" of the foot. An exercise sandal supplied with a "Spitzy Ball" is utilized for exercises.

134. Hullinger, C. W.: Insufficiency Fracture of the Calcaneus Similar to March Fracture of the Metatarsal, J. Bone & Joint Surg. **26**:751-757 (Oct.) 1944.

135. Raisman, V.: Spontaneous Fracture of the Calcaneus, Am. J. Surg. **65**:290-292 (Aug.) 1944.

136. Bingham, R.: Painful Feet: Congenital Insufficiency of the First Metatarsal Segment as a Cause Among Soldiers Recently Inducted into the Army, J. A. M. A. **124**:283-286 (Jan. 29) 1944.

137. Ilfeld, F. W.: Pes Planus: Military Significance and Treatment with Simple Arch Support, J. A. M. A. **124**:281-283 (Jan. 29) 1944.

138. Harris, R. I.: Foot Problems in the Army and Out of It, Bull. Vancouver M. A. **20**:273-276 (July) 1944.

139. Morton, D. J.: Foot Biomechanics: Functional Disorders and Deformities, M. Physics, 1944, pp. 457-566.

140. Bettmann, E. H.: The Human Foot: A Study of Its Structure and Function; New Functional Exercises, Arch. Phys. Therapy **25**:13-26 (Jan.) 1944.

In a report of 200 cases of foot disorders selected at random from the orthopedic clinic, Burnham [141] concluded that it would be better carefully to eliminate men with severe foot disorders at the induction centers because it is difficult under military conditions to treat these disorders so that the men can perform useful service. He believes that an improved orthopedic shoe should be issued to all soldiers who exhibit some foot weakness and that the shoe should protect the trainee against acute foot strain which leads to a pes planus. He also urges conservative measures rather than any radical operation with regard to the treatment in military service.

Hauser [142] states that the cause of most common foot disorders is functional decompensation or an imbalance between the work required of the foot and the capacity of the foot to do the work. Increase in load may cause this; standing on hard surfaces and wearing stiff-shanked shoes or shoes with high, narrow heels are causative factors. If the foot is in valgus position, it should be brought into varus position. Shoe corrections may help; a medical wedge on the heel and a comma-shaped bar higher on the outside, which does not go under the fifth metatarsal bone, to bring the anterior part of the foot into relative pronation, is recommended. In addition, the patient must be taught how to stand and how to walk and given special foot exercises. He must have rest periods which are controlled and functional exercises graded to individual needs.

Cleveland, Willien and Doran [143] have operated on 25 soldiers, including 1 officer and a nurse. In 22 of the cases the patients' subsequent fate is known. Half of the soldiers operated on for a single bunion returned to full duty, but only 13 per cent of those with bilateral bunions returned to full duty after operation. A comparison of different operative procedures led the authors to believe that Keller's operation is the method of choice because of good and quick healing, relatively simple after-treatment and a quicker recovery than after other operations. It is emphasized that in general the results of operations for hallux valgus in soldiers are unsatisfactory and that no operation for bunion should be undertaken, especially for bilateral bunions, unless there seems to be a reasonable prospect of the soldier's return to full duty.

Silver and Rusbridge [144] state that in view of the relative frequency of sprains of the ankle a method of treatment which returns the soldier to active duty in the shortest time with minimum of disability or hospitalization is greatly to be desired. At a station hospital in North Africa, 74 patients with severely sprained ankles were treated in nine months. Of these, 67 returned to active duty immediately and 2 had associated chip fractures of the lateral malleolus (1 returned to duty immediately and the other was overnight in the hospital because of no transportation). The cases of the 6 remaining patients, who were hospitalized, are analyzed.

The authors advocate a basket weave ankle strapping that does not encircle the leg at any point and that is applied with the foot at right angles to the leg and in neutral position regarding varus and valgus. Strapping the foot in inversion is condemned. Compound tincture of benzoin is applied to the skin prior to the strapping. Immediate use is recommended. They attempted to treat 5 patients with injections of procaine hydrochloride into the tender areas, without strapping. All obtained complete relief at once and walked out unassisted, but all returned the next day limping and with recurrence of disability and pain. They were then treated with a basket weave type of strapping, with good results.

Snow and Kraus [145] describe a method of administering procaine hydrochloride by iontophoresis for painful limitation of motion. The technic consists in the application of a solution of 1 per cent procaine hydrochloride and a 1:20,000 solution of epinephrine in 80 per cent alcohol. A gauze pad two to four layers thick is soaked in the solution and placed over the area to be treated. A crash towel is folded twice, soaked in isotonic solution of sodium chloride and spread over the gauze. A flexible metal electrode which is smaller than the towel is then placed over it. The positive pole of a source of galvanic current is attached to the metal electrode. The electrode is fixed by means of bandages. A neutral electrode of approximately the same size is moistened with weak saline solution and connected to the negative pole. The current is slowly applied and increased to 20 milliamperes and permitted to flow for twenty minutes.

141. Burnham, W. H.: Army Foot Disabilities, Mil. Surgeon **95**:20-24 (July) 1944.

142. Hauser, E. D. W.: Common Foot Disorders: Rehabilitation with Physiologic Exercises, Arch. Phys. Therapy **25**:93-95 (Feb.) 1944.

143. Cleveland, M.; Willien, L. J., and Doran, P. C.: Surgical Treatment for Hallux Valgus in Troops in Training at Fort Jackson During the Year of 1942, J. Bone & Joint Surg. **26**:531-534 (July) 1944.

144. Silver, C. M., and Rusbridge, H. W.: The Treatment of Sprains of the Ankle, M. Bull. North African Theat. Op. (no. 5) **1**:26-28 (May) 1944.

145. Snow, W. B., and Kraus, H.: Novocaine Iontophoresis for Painful Limitation of Motion, Mil. Surgeon **95**:360-362 (Nov.) 1944.

The current is gently reduced, and the electrodes are removed. The method of treatment is applicable in all cases in which there is limitation of motion due to muscle spasm. It has the advantage that there is no reaction or danger of infection, as with the injection of procaine hydrochloride.

[Ed. Note.—The use of local injection is valuable in the treatment of a sprained ankle. It relieves the pain and allows more normal function. It also relieves muscle spasm and permits replacement of the foot into normal position. For minor injuries in which the irritation and spasm are the greatest factors, local injection is often all the treatment that is required. In cases in which there is an extensive tear of the ligament, protection by means of the bandage described is indicated.]

The conditions of acute and recurrent dislocation of the angle joint, unaccompanied with fracture, do not appear to have achieved due recognition, according to Tucker.[146] His article reports six acute and eight recurrent dislocations of the ankle. The structural factors responsible for the stability of the ankle joint are described. The pathologic conditions of acute and characteristic recurrent dislocation of the ankle joint, the clinical features of dislocation and the method used to demonstrate the lesion are described in considerable accurate detail. Watson-Jones and Pennal recommend local anesthesia. When adequate anesthesia by means of pentothal sodium given intravenously has been obtained, the foot is grasped by one hand and the leg firmly grasped by an assistant. The foot is then forcibly inverted and the contour of the ankle region inspected. If the talus bone is tilted by this maneuver, a crease is evident across the front of the joint. By palpation a gap can be demonstrated anterolaterally between the tibia and the talus bone. Performance of the maneuver under the fluoroscope is recommended if possible, and positive results should be recorded on roentgenograms. Full inversion is all that is needed, and the ease of producing the dislocation is just as significant as the degree of displacement obtained. If the maneuver is performed with care, there is no need to inflict further damage.

The treatment recommended for acute dislocations is immobilization in a skintight plaster extending from the metatarsal heads to the tibial tuberosity. An army boot is fitted over the plaster, and a sponge rubber or felt is placed in the sole of the shoe for resilience. Walking is encouraged as soon as the pain has disappeared, and the patients soon develop a "heel-toe" type of walking, which is much preferred to the pivoting that occurs with Bohler's walking caliper. The cast is retained for ten weeks, and then normal movements are regained by supervised exercises. The results to date have been uniformly good. A recurrent dislocation of the ankle joint is disabling, and early recognition is urged. Severe sprain should receive appropriate attention in every case, and the manipulation described should be performed to test the integrity of the lateral ligaments. In all cases of acute dislocation, the ankle should be immobilized in plaster for about ten weeks. Injuries of this sort are probably responsible for the lay expression that "sprains of the ankle joint are often worse than a fracture."

[Ed. Note.—It is difficult to overemphasize the advantages of an examination of an injured ankle with the patient anesthetized or when a local anesthetic is utilized. Even the most skilful clinicians will miss significant pathologic conditions without the use of a general or a local anesthetic.]

Roth[147] describes a case of bilateral foot deformity, probably secondary to a congenital lesion of the rubrospinal tract, characterized by recurrent pes cavus, by complicating local infections from previous operative procedure and, later, by the appearance of dorsal exostoses and severe equinus. An anteroposterior tarsal wedge resection was useful in reconstruction of the right foot. The base of the wedge, which lay on the dorsum of the foot, was 1½ inches (3.8 cm.) wide. The apex lay in the posterior portion of the os calcis. Care was exerted to leave a sufficient thickness of bone under the distal articular surface of the ankle joint, so that its integrity would not be disturbed at operation.

Brown and Brown[148] present a case showing complete dislocation of the os calcis on the talus with 90 degree lateral rotation of the foot, the scaphoid bone being separated anteriorly from the talus. There was no fracture apparent. The dislocation occurred as a result of an external rotation force. Under pentothal sodium anesthesia, gentle manual traction and internal rotation was accompanied with sudden and nearly complete reduction of the dislocation. The slight displacement was corrected by removal of the original cast and recasting the extremity with the

146. Tucker, F. R.: The Stability and Instability of the Ankle Joint, J. Canad. M. Serv. **1**:411-417 (July) 1944.

147. Roth, F. B.: Use of Anteroposterior Tarsal Wedge Resection for Unusual Foot Deformity, Bull. Hosp. Joint Dis. **5**:26-30 (April) 1944.

148. Brown, M. J., and Brown, W. E.: Subastragaloid Dislocation, Am. J. Surg. **63**:276-277 (Feb.) 1944.

foot in full dorsiflexion. A cast was worn two weeks, and roentgen ray check-up showed a normal left ankle. On this day the cast was removed and weight bearing allowed. In four days the swelling was no longer present, and good motion of the joint was present without pain or stiffness. The patient was discharged to full duty in approximately four weeks after the injury.

Braun [149] expresses great satisfaction in the results he obtained by conservative therapy for bilateral acquired pes cavus deformities of severe degree in a 24 year old seaman. The treatment consisted in manual stretching of the contractures, restoration of the articular function by manipulation, fulcral felt blockings and strappings, physical therapy and an appliance to establish proper balance of the feet with weight bearing. He states that this case demonstrates what success can be obtained by an intelligent approach to this condition.

Boyd [150] reports 4 additional cases of talonavicular synostosis, the patients being a white girl of 10 years, a white boy of 10 years, the boy's father aged 45 and the boy's grandmother aged 72. The relationships of the last 3 patients suggest a hereditary nature of the condition.

Cohen [151] reports an additional case (20 previous cases have been reported in the literature) of osteochondritis dissecans of the astragalus. An operation two weeks after the trauma afforded an opportunity to note capsular damage (ecchymosis) which may account for this lesion. Necrosis was rapid and probably occurred immediately after the vascular damage or, at most, within several weeks. A description of the observations at operation for the removal of the osteochondritic body, the microscopic pathologic changes and the differential diagnostic points between an osteochondritic body and a posttraumatic osteochondral fracture are presented.

Croce and Carpenter [152] state that tearing of the plantaris tendon or tennis leg occurs most frequently in middle-aged persons. The syndrome does not cause much disability and has not been widely investigated. The immediate cause of this syndrome and the end result are not definitely known. The authors present a case history which is unusual for three reasons: 1. The cause was direct trauma. 2. The tear occurred near the origin of the muscle belly. 3. The injury resulted in a degenerative tumor of the muscle. It would seem that the plantaris tendon was torn from its origin along the linea aspera and probably deprived of its blood supply and a degenerative reaction of the belly of the muscle resulted.

Bickel and Moe [153] have described an operative procedure for the relief of paralytic calcaneal deformity of the foot resulting from poliomyelitis in 13 patients. The method consists in translocating the peroneus longus tendon by sliding it intact around the lateral border of the heel into a groove in the midline of the os calcis in an attempt to improve on the results obtained when the peroneal tendon is cut and transplanted into the tendo Achillis. They concluded that the best results were obtained when the operation was done on patients who had slight remaining power in the gastrocnemius muscles and fair or better power in the transposed peroneal muscle. It was their opinion that the results were strikingly better than if the peroneal tendon had been cut and then transplanted into the tendo Achillis.

A case of hereditary malformations of the hands and feet has been traced through four generations by Stiles and Pickard.[154] The defects in the extremities ranged from gross splitting of the hand or the foot to slight abnormalities of the digitis. An inspection of the pedigree reveals that the trait may be inherited as a single dominant. Modifying genes, environmental factors or a combination of both may be responsible for the extreme polymorphism of the character.

Experimental fractures in rabbits were treated by Blum [155] with phosphatase and calcium glycerophosphate with and without an anchoring medium (an alginate gel) employed to prevent the too rapid diffusion of the introduced enzyme from the region of the bone gap. Enzyme and substrate were either injected into the gel, which had been pressed into the bone gap, or were injected into the bone gap, in which the gel was subsequently formed in situ. Progress of repair of the bone was followed by roentgenograms and by histologic examination. The treated fractures showed acceleration of repair as compared with untreated controls.

149. Braun, G. S.: Bilateral Pes Cavus: A Case Report, U. S. Nav. M. Bull. **43**:346-348 (Aug.) 1944.

150. Boyd, B. H.: Congenital Talonavicular Synostosis, J. Bone & Joint Surg. **26**:682-686 (Oct.) 1944.

151. Cohen, H. H.: Osteochondritis Dissecans of the Astragalus, Bull. Hosp. Joint Dis. **4**:86-91 (Oct.) 1943.

152. Croce, E. J., and Carpenter, G. K.: Rupture of the Plantaris Muscle, J. Bone & Joint Surg. **26**:818-820 (Oct.) 1944.

153. Bickel, W. H., and Moe, J. H.: Translocation of the Peroneus Longus Tendon for Paralytic Calcaneus Deformity of the Foot, Surg., Gynec. & Obst. **78**:627-630 (June) 1944.

154. Stiles, K. A., and Pickard, I. S.: Hereditary Malformations of the Hands and Feet, J. Hered. **34**: 341-344 (Nov.) 1943.

155. Blum, G.: Phosphatase and the Repair of Fractures, Lancet **2**:75-78 (July 15) 1944.

Fienberg [156] reports a case of madura foot, or mycetoma, in a native American who had not traveled beyond the limits of the continental United States. This is the sixth case to be reported from the United States and Canada in which the etiologic agent was Monosporium apiospermum, a true fungus. It should be noted, he says, that the granulomatous tissue alone was nonpathognomonic, and it was only when the masses of fungi forming the granules were found within the tissue sections that the diagnosis was definite. The most important part of the disease is the lack of efficacious therapeutic means for saving the foot. Amputation was not employed in this case because the patient could still use the foot, but it is believed that eventually it will have to be done.

King [157] describes a simple operation to reduce and maintain an overlapped or dorsally subluxated fifth toe. The extensor digitorum longus tendon to the fifth toe is divided distally. The capsule is stripped from the joint, as well as periosteum in that area, until the articulation is free. The tendon is run through a drill hole bored through the head of the first metatarsal bone. The capsule and periosteum are fastened beneath the joint to hold the proximal phalanx down in line with the first metatarsal bone. The toe is held by means of adhesive strapping after the wound is dressed.

Jones [158] describes the relationships and enumerates the misnomers of the ligaments involving the talocalcaneal joints. He advises correction and uniformity in nomenclature and offers terminology. He states that when it is realized that there is no strong and continuously elongated interosseous ligament binding the talus bone to the calcaneus bone over the whole length of the canalis tarsi, it is easy to appreciate the fact that movement between the two bones is free. The additional knowledge that the actual bond between the talus and calcaneus bones is a discrete ligament (ligamentum cervicis), joining their respective necks between the forward extremities of their anterior and posterior articulations, makes it easy to understand how the foot is, so to speak, hung in gimbals between the supratalaloid and the infrataloid joint. At the supratalaloid (ankle) joint, the foot moves up and down in extension and flexion. At the subtaloid (talocalcaneal) joint, it turns inward and outward (inversion and eversion), and the ligamentum cervicis is the pivot around which this complex rocking and screwing side to side movement takes place. Unless one has this knowledge, the beautiful reciprocally curved articular surfaces of the talocalcaneal joints are meaningless, and one of the most essential mechanisms of the foot is in danger of going unrecognized.

Berridge and Bonnin [159] describe the technic of arthrography of the ankle; the appearances of the normal arthrograph of the ankle are shown. The anatomic features of injuries to the ankle demonstrated by arthrography are enumerated. Its value in the supplementary examination of lesions of the ankle is small and confined to rare lesions, partial diastasis and distinction of old and recent injury. More information of diagnostic value can be obtained by roentgenologic examination of the joint under strain. The appropriate cases in which strain should be employed and the types of strain used are enumerated as follows: (1) inversion (tibial flexion) of the hind part of the foot—used in suspected cases of damage to the fibular collateral ligament and its most frequently injured fasciculus, the calcaneofibular band; (2) eversion—used for suspected rupture of the deltoid ligament; (3) plantar flexion (in hyperextension injuries the anterior fasciculi of both collateral ligaments may be torn), and (4) external rotation of the foot—used in cases of doubtful diastasis and results in opening the syndesmosis. The essential importance of this method is the distinction between sprains and complete ligamentous rupture. The more often it is carried out, they say, the more surprised one will be to discover complete ruptures with the minimum physical signs. A similar view of the uninjured ankle is a distinct value. Pentothal sodium anesthesia is advised in preference to local anesthesia for the roentgenograms taken under strain.

Gamble [160] (who is a Doctor of Surgical Chiropody) presents a method of taking roentgenograms from various angles and composite roentgenograms of the foot while bearing weight, without changing the position of the foot. Such roentgen studies must aid in diagnosis, prognosis and therapy.

156. Fienberg, R.: Madura Foot in Native American: A Case of Monosporosis, Am. J. Clin. Path. **14**:239-246 (April) 1944.

157. King, B. B.: Lantzounis Periosteo-Capsuloplasty for Congenital Dorsal Subluxation of Congenital Overlap of the 5th Toe, South. M. J. **37**:614-617 (Nov.) 1944.

158. Jones, F. W.: The Talocalcanean Articulation, Lancet **2**:241-242 (Aug. 19) 1944.

159. Berridge, F. R., and Bonnin, J. G.: The Radiographic Examination of the Ankle Joint Including Arthrography, Surg., Gynec. & Obst. **79**:383-389 (Oct.) 1944.

160. Gamble, F. O.: A Special Approach to Foot Radiography, Radiog. & Clin. Photog. (no. 3) **19**:78-80, 1943.

Bennett [161] describes an operative procedure for the removal of the buried nail edge, the matrix of the nail edge and the heaped-up hypertrophied nail wall, with preservation of the overlying skin for a primary plastic closure of the defect. Healing takes place by primary union in a high per cent of the cases, and the postoperative disability is thereby reduced from approximately three weeks to less than one week. Local abscesses must be allowed to subside before the radical operation is attempted. Permanent cure depends on thorough destruction of the matrix of the nail margin.

Swart [162] presents 1 case of a tumor involving the lateral branch of the medial plantar nerve, with relief following resection for complaints of metatarsalgia.

Montgomery and Montgomery [163] state that many of the remedial defects in feet that disqualified men for military service or required that they be restricted to limited activity resulted from neglected bony malformations that later caused various keratotic lesions. Preventive measures are frequently neglected. Treatment for minor defects of the feet, regardless of the symptomatology or disability, is important in preventing secondary disabling keratotic lesions. The most common of these are the callus (callositas), corn (clavus) and wart (verruca). Differential diagnostic errors and mistreatment with radiotherapy resulting in unfortunate sequelae are frequent. Differentiation of these lesions from plantar radiodermatitis and administration of proper treatment as outlined in this paper would prevent many unnecessary bad results. Treatment for the various lesions is discussed.

[Ed. Note.—This is an especially good article and is well illustrated. Normal functional use of the feet, unhampered by ill fitting footgear and on occasion aided by the judicial use of pads and alterations in the shoes, is an effective preventive and curative measure in the majority of cases. Frequently, however, it is neglected because the results are often not sudden and spectacular. The authors have shown how contributory remedial causative factors are in the production of disabling hyperkeratotic lesions in the military services, and they are no less disabling in civilian life.]

161. Bennett, L. C.: Radical Operation with Plastic Closure, for Cure of Ingrowing Nails, Mil. Surgeon **94**:361-364 (June) 1944.

162. Swart, H. A.: New Cause of Metatarsalgia; case, West Virginia M. J. **40**:12-13 (Jan.) 1944.

163. Montgomery, R. M., and Montgomery, A. H.: Common Hyperkeratotic Lesions of Foot, J. A. M. A. **124**:756-761 (March 18) 1944.

According to DeBakey,[164] vascular spasm results from trauma that directly or indirectly affects the vascular structures. Injury to distant tissues or minimal manipulation of a fracture may be followed by a reflex vasospasm. The degree of vasospasm varies considerably, from localized constriction with consequent minimal ischemia to a more extensive and generalized involvement, especially of the collateral circulation, with sufficient ischemia to produce actual gangrene. Moreover, the vasospasm may persist for varying periods and as long as, or even longer than, forty-eight to seventy-two hours. Since the disturbance is apparently due to the development of a vasomotor reflex initiated in the traumatized tissues and since vasoconstrictor impulses are transmitted by way of the sympathetic nerve fibers, interruption of these impulses in the circuit prevents vasospasm and permits vasodilatation. This may be done by débridement of surrounding traumatized tissue, periarterial sympathectomy or procaine hydrochloride block of the regional sympathetic ganglions. The last-named procedure is probably the most effective method of producing maximum vasodilatation in these cases and should be employed for all types of peripheral vascular injuries accompanied with manifestation of vasospasm. It may be necessary to repeat the sympathetic block at least once or twice daily for several days. The technic of procaine hydrochloride block of the lumbar sympathetic ganglions and of the stellate ganglion is presented.

According to Nomland,[165] the most important cutaneous manifestations that occur on the foot in association with circulatory disorders are those which occur with peripheral vascular disease. He presents descriptive identifications and suggests therapeutic and precautionary measures for the following: arteriosclerosis obliterans, thromboangiitis obliterans, Raynaud's syndrome, acrosclerosis, erythromelalgia, immersion foot, trench foot, shelter foot and such vascular anomalies as capillary angioma, spider nevus, small and large cavernous angiomas, lymphangioma and diffuse lymphangiomatosis. [Ed. Note.—Differential diagnosis and treatment are exceptionally well presented in this article.]

Goldstone and Corbett [166] state that it appears that immersion foot may be regarded as a mas-

164. DeBakey, M.: Traumatic Vasospasm, Bull. U. S. Army M. Dept., February 1944, no. 73, pp. 23-28.

165. Nomland, R.: Cutaneous Manifestations of the Circulatory Disorders of the Foot, J. A. M. A. **124**:747-750 (March 18) 1944.

166. Goldstone, B. W., and Corbett, H. V.: Aetiology of Immersion Foot, Brit. M. J. **1**:218-219 (Feb. 12) 1944.

sive chilling and ischemia of all the various tissues of the foot or hand. These are successively affected in the inverse order of their biologic fortitude. The complication of duodenitis with duodenal hemorrhage is described. It is suggested that this may be due to the absorption of toxins from the damaged area. The similarity with Curling's duodenal ulcer in burnt patients is noted.

White and Warren,[167] with regard to immersion foot, believe that they have established the fact that there are two definite factors which account for this painful syndrome. In the early phase of inflammation pain is due to anoxia of the injured superficial tissues and nerve endings. Pain of this type can be controlled by cooling the legs, as this lowers cellular metabolism and makes the reduced demand for oxygen commensurate with the limited supply which can be furnished by the thrombosed superficial blood vessels. The second type of pain is characterized by aching and rigidity of the toes and comes on later, after several days have elapsed after a rescue. This may cause prolonged disability.

Edwards, Shapiro and Ruffin[168] state that exposure of the foot for several days to cold, damp weather frequently results in a condition known as trench foot. The outside temperature required to cause trench foot is not so low as that required for frostbite, mainly because of the contact of the extremity with water. There is an anoxia of the tissues and the muscles which results in damage to nerves. When the feet get warm after exposure, the toes tingle, burn or ache. In this period of too rapid thawing, much damage may be done. The capillary vessels may be injured. The condition is divided into four degrees according to severity: (1) cool and moist, (2) cold and cyanotic, (3) cold and cyanotic with blebs and (4) gangrenous. The treatment consists in washing the feet with soapy water (70 F.) and then exposing them to warm temperature. Absolute rest in bed is advised and then gradual calisthenics followed by rehabilitation exercises. In case of severe damage, injection of procaine hydrochloride into the lumbar sympathetic chain was tried, but with unsuccessful results. Lumbar sympathectomy seemed to be of some use in grade 4, in which gangrene was present. Prophylactic measures, principally keeping the feet dry and general hygienic measures for the foot, are recommended.

Baker and Kuhn[169] conclude that Morton's metatarsalgia syndrome is caused by a tumor in the fourth plantar digital nerve. The cause of this lesion is questionable, but the anatomic relationships of the nerve and the pathologic observations indicate that it is a degenerative fibrosis of the nerve with neuromatous proliferation resulting from, or irritated by, repeated trauma. The characteristic history of the syndrome and the presence of a localized tenderness to deep palpation in the third web space or between the third and fourth metatarsal heads on the dorsal surface of the foot make the diagnosis simple. Excision of the tumor relieves the symptoms.

167. White, J. C., and Warren, S.: Causes of Pain in Feet After Prolonged Immersion in Cold Water, War Med. **5**:6-13 (Jan.) 1944.

168. Edwards, J. C.; Shapiro, M. A., and Ruffin, J. B.: Trench Foot: Report of Three Hundred and Fifty-One Cases, Bull. U. S. Army M. Dept., December 1944, no. 83, pp. 58-66.

169. Baker, L. D., and Kuhn, H. H.: Localized Degenerative Fibrosis with Neuromatous Proliferation of Fourth Plantar Nerve, South. M. J. **37**:123-127 (March) 1943.